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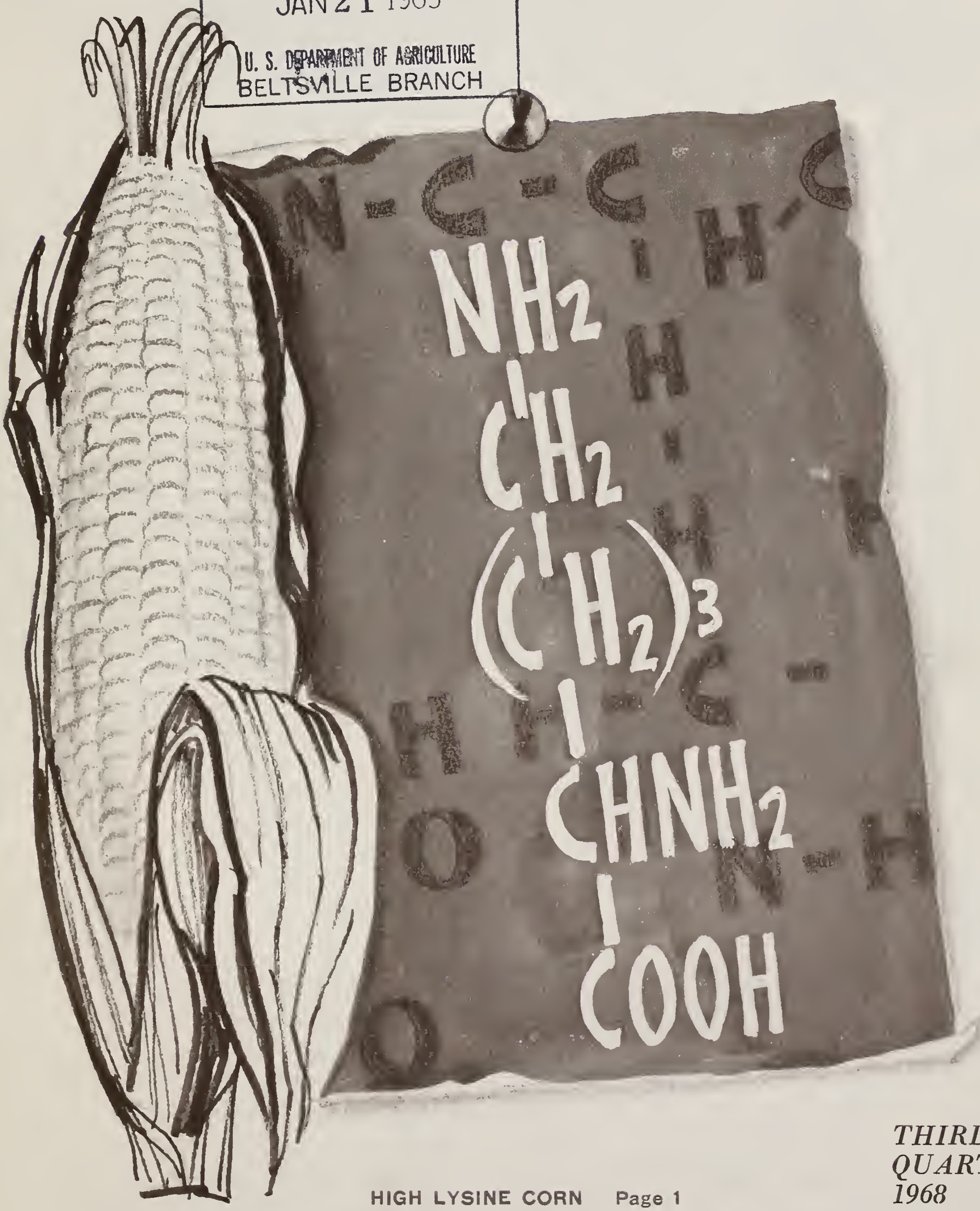

THIRD QUARTER 1968

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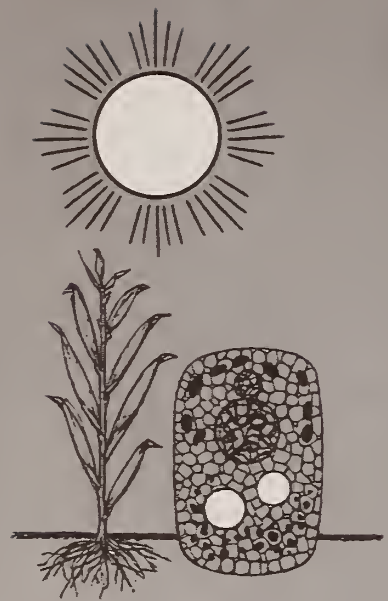

AGRICULTURAL SCIENCE REVIEW

Third Quarter 1968 Vol. 6 No. 3

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Editorially Speaking . . .

A survey of our correspondence files reveals some interesting commentary about the high-lysine corn article in this issue of *Review*.

The original invitation went out to author Mertz the same week he made his first official announcement about the *opaque-2* achievement. Although the time lapse between invitation and publication was longer than usual—about 3 years—there were sound reasons for the delay.

We readily granted a request to defer the writing until Dr. Mertz and his associates could complete feeding trials to determine the practicability of *opaque-2*. After these data became available, the full significance of the achievement began to dawn on other people who made demands on the time of Drs. Mertz and Nelson. Speaking engagements, press and magazine interviews, and official reports—all had to be fulfilled. The pattern is always the same for any scientist who announces a breakthrough. On top of all this came a full-scale conference on high-lysine corn and the usual extra activity such an event seems to generate. Meanwhile the months slipped by.

Only after relative quiet began to prevail around Dr. Mertz's laboratory did he pick up his pen to begin writing a studied, objective review of what had happened. The result, we believe, was worth waiting for. We think busy administrators will appreciate getting the whole story told in succinct, summary fashion. A further bonus feature is the author's perceptive analysis of what needed research lies ahead if the world hopes to capitalize fully on this "super corn."

Only one sour note has come out of all this—and it's one that properly bothers an ag science editor. Even with the extra publicity, there are too many people around who never even heard of high-lysine corn. Some of them, we regret to say, are actually working in agriculture. But they have heard about a fancy-sounding chemical in a popular toothpaste. At least that's what your editor's informal poll showed. Is there a solution for this dilemma in agriculture?—W. W. K.

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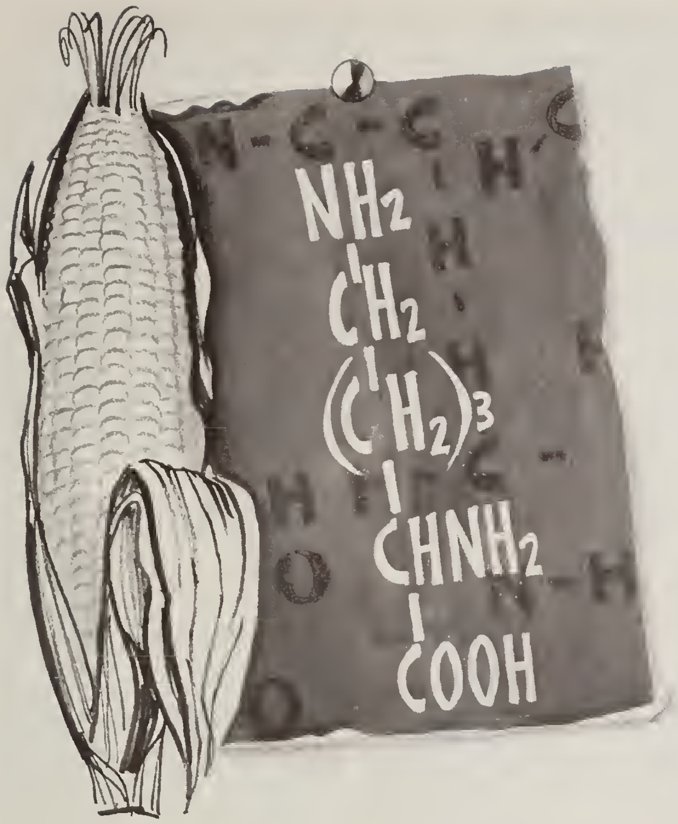


HIGH LYSINE CORN

EDWIN T. MERTZ

THE *opaque-2* and *floury-2* mutant genes in corn (*Zea mays*) have been known for more than 30 years (*10*)[1]. That they profoundly affect the protein composition of the endosperm was discovered only recently (*14*).

Nutritionists became aware of the poor quality of corn protein when Osborne and Mendel showed in 1914 that zein, the major protein of corn, was nearly devoid of lysine and tryptophan. A diet containing zein as the only protein was incapable of supporting growth in young rats. Adding pure lysine and tryptophan together (but not singly) to the zein gave good growth, and demonstrated clearly for the first time that these amino acids are essential dietary components (20).

Our search for an endosperm with less zein (and, hopefully, more glutelin, the "complete" protein of endosperm) began in 1958 when we determined microbiologically the amino acid composition and chemically the zein content of several United States and Guatemalan maize varieties (*4*). Two years later we examined the zein levels of 10 maize mutants, including two floury types, *floury-1* (fl_1) and soft starch (h). We were getting "warm" with the floury types, but unfortunately did not test all of the known floury mutants (*15*).

In 1963, Dr. Oliver E. Nelson, professor of genetics, Department of Botany and Plant Pathology, Purdue University, joined the writer and his graduate student, Lynn S. Bates, in the search for a low zein maize. Our recently acquired automatic amino acid analyzer was pressed into service to handle the samples selected by Dr. Nelson.

Records (*14*) show that in the fall of 1963 four floury maize mutants were initially submitted as promising samples for analysis by Nelson (*floury-1, floury-2, opaque-1, opaque-2*). On November 18, 1963, Bates obtained an unusually high recorder tracing for lysine on one of these samples. The tracing was from the *opaque-2* sample (4 percent lysine based on endosperm protein). Analyses of the other three samples soon revealed that *floury-2* was also high in lysine (3.4 percent) but that *floury-1* and *opaque-1* were normal (2 percent).

[1] Italic numbers in parentheses refer to Literature Cited, p. 6.

TABLE 1.—*Amino acids in endosperms (E) and whole kernels (K) of normal and high lysine maize (grams per 100 g protein)*

Amino Acid	W64A+ (E)	W64Ao$_2$ (E)	1964 Floury-2 (E)	1967 Normal (K)	1967 Opaque-2 (K)
Lysine	1.6	3.7	3.4	3.0	4.8
Tryptophan [1]	0.6	1.2	0.9	0.7	1.3
Histidine	2.9	3.2	2.4	2.6	3.3
Arginine	3.4	5.2	4.3	4.9	8.5
Aspartic acid	7.0	10.8	10.9	9.2	10.8
Glutamic acid	26.0	19.8	20.6	22.6	17.5
Threonine	3.5	3.7	3.6	4.1	4.0
Serine	5.6	4.8	5.3	5.6	4.8
Proline	8.6	8.6	10.0	9.6	7.6
Glycine	3.0	4.7	3.7	4.7	4.8
Alanine	10.1	7.2	8.6	9.2	6.6
Valine	5.4	5.3	5.6	5.7	5.1
Cystine	1.8	1.8	1.6	1.7	1.7
Methionine	2.0	1.8	3.4	1.3	2.1
Isoleucine	4.5	3.9	4.2	4.2	3.4
Leucine	18.8	11.6	13.9	14.6	9.1
Tyrosine	5.3	3.9	4.7	5.2	4.0
Phenylalanine	6.5	4.9	5.4	5.8	4.5
Percent protein					
	12.7	11.1	13.6	9.0	11.6

[1] Unpublished colorimetric method (Cain, Mertz and Nelson).

ENDOSPERM CHEMISTRY

STUDIES with isogenic lines of maize (*19*) differing only at the *opaque-2* locus (W64A+ and W64Ao$_2$, cols. 2 and 3, table 1) show that the endosperm of *opaque-2* contains twice as much lysine and tryptophan, 50 percent more arginine, aspartic acid and glycine, and 30 percent less alanine and leucine. Similar changes are observed in the *floury-2* endosperm (col. 4, table 1) (*19*). The primary cause of these changes is a marked decrease in the prolamine (alcohol-soluble) protein, zein (*14*). Physically, the reduction in zein in both *opaque-2* and *floury-2* genotypes is associated with the disappearance (or major decrease) in size of the protein bodies of the endosperm. This was demonstrated by Wolf and coworkers (*24*) using the light and the electron microscope.

Opaque-2 and *floury-2* genes apparently act as prolamine suppressants in the developing endosperm. This action upsets the normal balance between prolamine and glutelin (*12*) synthesis, the latter becoming dominant. In normal maize endosperm, prolamine (zein) accounts for about 50 percent, and glutelin for about 25 percent, of the total protein (*4*). In *opaque-2* and *floury-2* endosperm, these values are reversed (*14*). In addition, there are relative increases in the amounts of nonzein, nonglutelin proteins of free amino acids (*16*). All fractions which increase contain substantially higher levels of lysine and tryptophan than does zein (*16*).

Most lines into which the *opaque-2* gene has been incorporated show several-fold increases in endosperm ribonuclease at about 3 weeks post-pollination. All show an increase at maturity. This is not observed consistently in the *floury-2* endosperm (*9*, *8*). No strong evidence for the synthesis of new proteins has been obtained with either mutant, and at present we assume that the amino acid changes observed in the endosperm of the two high lysine types are due to shifts in the relative proportions of the normal endosperm proteins.

The *opaque-2* gene has little if any effect as a zein suppressant when present in one or two doses

in the triploid endosperm (i.e., $++o_2$ and $+o_2o_2$). The lysine-raising effect is observed only with three doses of the gene ($o_2o_2o_2$) (*2*). In contrast, the *floury-2* gene is semidominant. Nearly constant increases in lysine as percent of the endosperm protein are observed with each added dose of the mutant gene (*2*).

The amino acid composition of *opaque-2, floury-2* and normal maize embryos is similar (*16, 13*). The *opaque-2* and *floury-2* genes appear to modify the amino acid composition of the endosperm only.

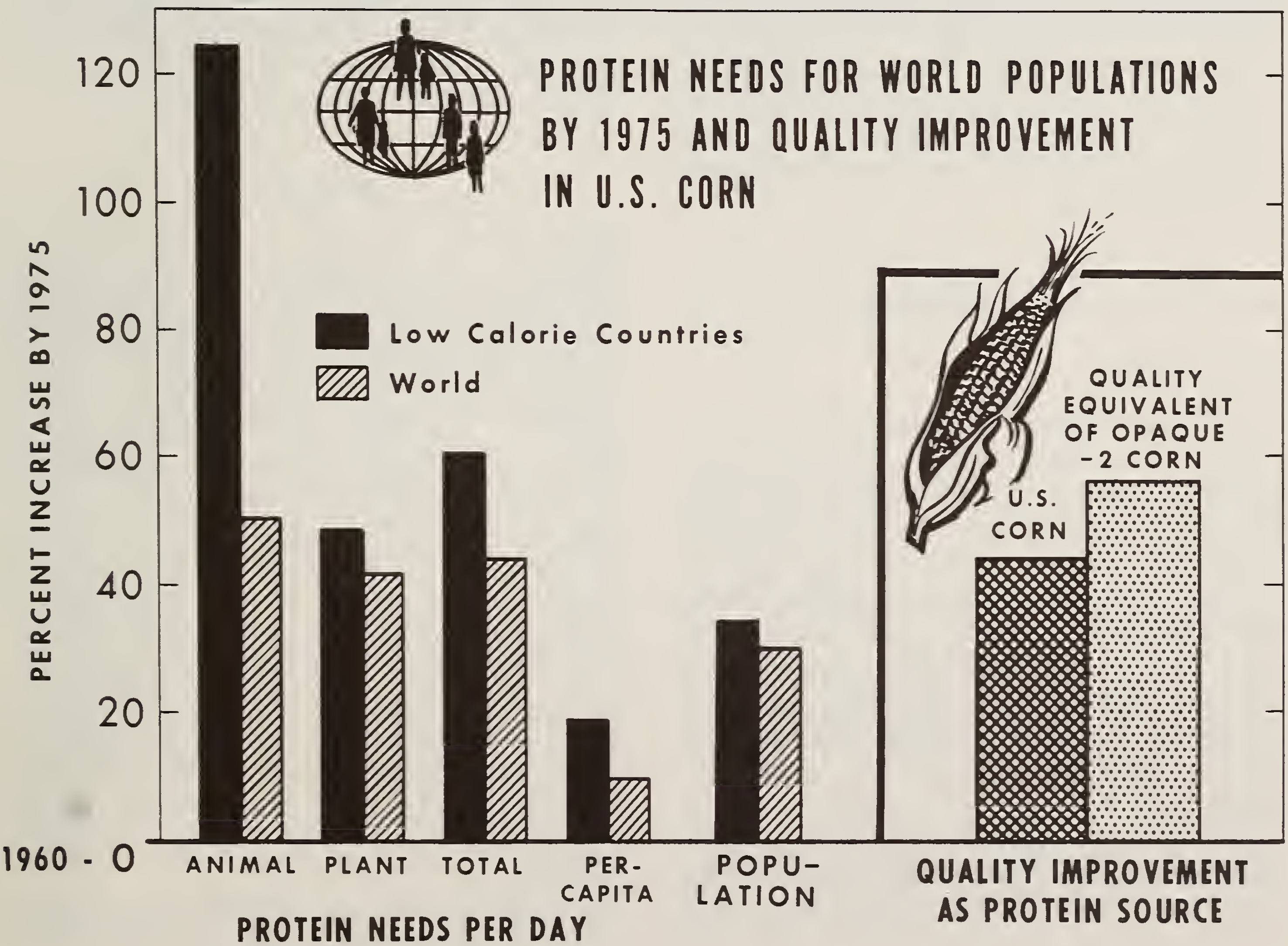
POSSIBLE EFFECTS IN OTHER CEREALS

Rice

CAGAMPANG and coworkers (*5*) found the average ratio of prolamine to glutelin in brown or milled rice to be 3:83. A search for mutations suppressing prolamine synthesis in rice as *opaque-2* does in maize therefore would not appear to be very promising.

Wheat

THE prolamine to glutelin ratio in wheat endosperm is approximately 55:45. Reduction of this ratio to approximately 33:67 should theoretically produce the effect previously observed in *opaque-2* maize endosperm. However, our analyses of purified wheat gliadin and glutenin prepared from Wichita hard red winter wheat gave values of 0.85 percent and 1.3 percent lysine, respectively (corn zein contains 0.2 percent, corn glutelin 4 to 5 percent lysine). The lysine in a 55:45 mixture of gliadin and glutenin would be 1.0 percent, and in a 33:67 mixture it would be 1.15 percent. Suppressing prolamine synthesis in wheat therefore only slightly increases the lysine of the prolamine-glutelin mixture, whereas in *opaque-2* maize a 33:67 mixture of zein and



glutelin would contain approximately 3.3 percent lysine.

The assumption has been made that wheat glutenin would not increase in lysine. Actually, *opaque-2* corn glutelin contains about 25 percent more lysine than normal corn glutelin (*16*). If a gene similar to *opaque-2* depressed prolamine synthesis and at the same time tripled the lysine level of wheat glutenin, a "high-lysine" wheat would be produced. These calculations suggest that both suppression of prolamine synthesis and a major increase in glutenin lysine would be required to increase the lysine in wheat to more desirable levels.

Sorghum

SORGHUM contains a high level of prolamine in the endosperm (about 60 percent) and the prolamine-glutelin ratio is approximately 3:1. Preliminary studies in the author's laboratoryy (*16*) indicate that kafirin, the prolamine of sorghum, contains less than 0.2 percent lysine, whereas the glutelin contains 2.5 to 3 percent lysine. Suppression of kafirin synthesis by introduction of the *opaque-2* gene (or its equivalent in sorghum) should markedly elevate the lysine level and improve the protein value of the endosperm in this crop. A search for a mutation homologous to *opaque-2* is therefore well justified in the case of sorghum.

NUTRITION

Opaque-2 Maize

SINCE lysine and tryptophan are the limiting amino acids in maize, *opaque-2* maize should be superior to normal maize as a source of proteins for animals and man. This has been demonstrated by our group in rats (*17*), by Cromwell *et al* in pigs (*7*), by Bressani in young children (*3*), and by Clark in adult humans (*6*). The amino acid composition of whole kernels of normal and *opaque-2* maize typical of that fed in the above nutrition tests is shown in columns 5 and 6, table 1. Note the increased levels of lysine, tryptophan and protein in the *opaque-2* kernels.

Krider (*11*) has estimated that if *opaque-2* maize can be produced at the same cost as present hybrids, it would save corn belt hog farmers more than $140 million a year in feed costs.

When used as the only source of protein in young children's diets adequate in minerals and vitamins, the value of the mutant approaches that of skim milk (*3*). In recent tests by Pradilla and Harpstead (*21*), children suffering from kwashiorkor (severe protein deficiency disease) recovered when *opaque-2* maize served as their only source of protein.

Floury-2 Maize

THE superior protein value of *opaque-2* maize in the diets of both animals and man has been well documented. However, much less chemical and nutritional data are available on *floury-2* maize. The inbred selections studied at Purdue have a higher methionine level in the endosperm than either normal or *opaque-2* varieties (see col. 4, table 1), suggesting that *floury-2* maize may be superior to normal or *opaque-2* maize as a source of this sulfur amino acid. *Floury-2* maize and the double mutant, *floury-2, opaque-2,* were better than normal maize as protein sources in rat feeding tests (*23*). The double mutant has an amino acid composition similar to that of the single mutants, but unlike *floury-2* and *opaque-2* the double mutant has an almost normal (translucent) endosperm (*18*).

BREEDING

HIGH lysine corn presents two important challenges to the plant geneticist. One of these is the development of high protein varieties. Our group reported in 1965 (*17*) that incorporation of the *opaque-2* gene into Illinois high protein maize containing 18–20 percent protein doubled the lysine level of the endosperm. The same result is obtained with the *floury-2* gene (*18*). A level of 15 percent of good quality protein is adequate for most young growing animals; a level of 12 percent is adequate for the mature animal. Breeding programs are therefore justified to develop high lysine maize selections containing 12 to 15 percent of total protein. *Opaque-2* and *floury-2* selections in present commercial inbred lines tend to run higher in total protein because of increased germ to endosperm ratios. Thus, protein levels of 10–12 percent are regularly encountered. Normal hybrids seldom exceed 9 percent.

The second important challenge is to improve yield. Simple conversion of present commercial in-

In this close-up photo of kernels on an ear of corn, *opaque-2*—the mutant gene—is clearly distinguishable in the center. (Photo by Corn Industries Research Foundation)

breds to their *opaque-2* (or *floury-2*) counterparts does not guarantee high-yielding hybrids. *Opaque-2* and *floury-2* endosperms tend to have a lower density than normal endosperms, because they lack translucent (high density) material. This lowers kernel weight. However, studies at Illinois (*1*) and Purdue (*22*) show that the yield reductions encountered with the *opaque-2* and *floury-2* genes are a function of the genetic background. Thus, a proper complement of modifying genes can increase the size of the kernel or the number of kernels per ear enough to compensate for the lower density of the starchy mutant.

Density can also be increased by selection (or by forming the double mutant). In recent studies at Purdue (*22*), the average yield reduction in *opaque-2* single cross hybrids was approximately 15 percent of their normal counterparts. In some lines there was no yield reduction. These, however, were not the highest yielding lines. We concluded that it should be possible, by proper selection, to develop *opaque-2* lines which are equal to the present highest yielding normal lines.

FUTURE PROSPECTS

THE development of high yielding *opaque-2* and *floury-2* varieties is an important research problem for the maize producing regions of the world. Varieties adapted to one region may not perform well in others. Each region must therefore develop its own. Such a breeding program requires the continued team work of geneticists and biochemists. If high yielding varieties of *opaque-2* and *floury-2* maizes with 12 to 15 percent protein are developed, mankind will have available—for the first time in history—a "super grain" which contains everything for complete nutrition except a few inexpensive minerals and vitamins.

LITERATURE CITED

(*1*) Alexander, D. E.
1966. problems associated with breeding opaque-2 corns, and some proposed solutions. Proc. High Lysine Corn Conf. (Corn Industries Res. Fdn., Washington, D.C.) 143–147.

(*2*) Bates, L. S.
1966. amino acid analysis. Proc. High Lysine Corn Conf. (Corn Industries Res. Fdn., Washington, D.C.) 61–66.

(*3*) Bressani, R.
1966. protein quality of opaque-2 maize in children. Proc. Conf. on High Lysine Corn (Corn Industries Res. Fdn., Washington, D.C.) 34–39.

(*4*) Bressani, R. and Mertz, E. T.
1958. studies on corn proteins. iv. protein and amino acid content of different corn varieties. Cereal Chem., 35: 227–235.

(*5*) Cagampang, G. B., Laurdes, J., Espiritu, S. G., Santiago, R. G., and Juliano, B. O.
1966. studies on the extraction and composition of rice protein. Cereal Chem., 43: 145–155.

(*6*) Clark, H. E., Allen, P. E., Meyers, S. M., Tuckett, S. E., and Yamamura, Y.
1967. nitrogen balances of adults consuming opaque-2 maize protein. Am. J. Clin. Nutrition, 20: 825–833.

(*7*) Cromwell, G. L., Pickett, R. A., and Beeson, W. M.
1967. nutritional value of opaque-2 corn for swine. J. Animal sci., 26: 1325–1331.

(*8*) Dalby, A.
Unpublished data.

(*9*) Dalby, A. and Davies, I. I.
1967. ribonuclease activity in normal and mutant endosperm of maize. Science, 155: 1575–1576.

(*10*) Emerson, R. A., Beadle, G. W., and Fraser, A. C.
1935. summary of linkage studies in maize. Cornell Univ. Agr. Expt. Sta. Mem. No. 180.

(*11*) Krider, J. L.
1966. Proc. 9th annual Pork Industry Conf. Nov. 18, Waterloo, Iowa.

(*12*) Lloyd, N. E. and Mertz, E. T.
1958. studies on corn proteins. iii. the glutelins of corn. Cereal Chem., 35: 156–168.

(*13*) Mertz, E. T.
1966. better protein quality in maize. Adv. Chem. No. 57, 228–242.

(*14*) Mertz, E. T., Bates, L. S., and Nelson, O. E.
1964. mutant gene that changes protein composition and increases lysine content of maize endosperm. Science, 145: 1701–1705.

(*15*) Mertz, E. T., Kramer, H. H., and Chun, W. L.
1960. extraction and characterization of corn proteins using a copper method. Purdue Agr. Exp. Sta. Annual Report, Project 1026.

(*16*) Mertz, E. T. and Nelson, O. E.
Unpublished data.

(*17*) Mertz, E. T., Veron, O. A., Bates, L. S., and Nelson, O. E.
1965. growth of rats on opaque-2 maize. Science, 148: 1741–1742.

(*18*) Nelson, O. E.
1966. opaque-2, floury-2, and high-protein maize. Proc. High Lysine Corn Conf. (Corn Industries Res. Fdn., Washington, D.C.) 156–160.

(*19*) Nelson, O. E., Mertz, E. T., and Bates, L. S.
1965. second mutant gene affecting the amino acid pattern of maize endosperm proteins. Science, 150: 1469–1470.

(*20*) Osborne, T. B., and Mendel, L. B.
1914. amino acids in nutrition and growth. J. Biol. Chem., 17: 325–349.

(*21*) Pradilla, A. and Harpstead, P.
1968. Unpublished data. Dept. of Pediatrics, Universidad del Valle, Cali, Colombia, South America.

(*22*) Sreeramulu, C. and Bauman, L. F.
1968. diallele analysis of yield in maize hybrids with opaque endosperm. Paper presented at Am. Soc. Agron. Meetings, New Orleans. November 1968.

(*23*) Veron, O. A.
1967. the determination of the protein quality of opaque-2, floury-2, floury-2-opaque-2, and high protein opaque-2 maize. Ph. D. Thesis, Purdue University, Lafayette, Ind.

(*24*) Wolf, M. J., Khao, U., and Seckinger, H. L.
1967. subcellular structure of endosperm protein in high lysine and normal corn. Science, 157: 556–557.

What Will the Payoff Be on High-Lysine Corn?

As soon as the feasibility of high-lysine corn production became reasonably certain, speculation began as to the possible effects it would have on the agricultural economy. The range of forecasts was varied; in general, they reflected a high degree of optimism for this latest research achievement.

One prediction, however, has failed to hit the mark, although the outcome is a happy one. In 1966 it was estimated that commercial seed supplies of the new high-protein strain would not be available for 5 or 6 years. But at least 3 seed companies have already announced that they expect to have enough seed to plant 18,000 acres in the spring of 1969. The extent of further expansion of seed production will depend, of course, on farmer demand.

Although the research history of high-lysine corn, in terms of years of research effort, approximately matches that of hybrid corn, it would appear that the complexity of the high-lysine problem was the greater of the two. A higher investment of funds and man-years, coupled with the availability of more sophisticated research equipment and the pressure of world food problems, undoubtedly hastened the day of success for high-lysine corn. One must recognize also the intensive and wholehearted cooperation of private industry. Obviously, all these factors helped to shorten the timetable.

Better Human Nutrition

High on the list of possible benefits from *opaque-2* corn is the boost it could give to the nutritional status of less-developed countries where maize is the chief food.

In Central America, for example, corn is the basic food of half the 200 million people. Diets in parts of Africa are also high in corn. But because of an incomplete amino acid balance, ordinary corn has definite disadvantages as a sole protein source for man. (The same principle, of course, also applies to domestic animals.)

Dr. Aaron Altschul, noted USDA protein researcher, says inadequate protein in the diet is especially serious for sensitive populations such as children, pregnant and nursing women, and the ill or injured. In children, for example, the brain normally reaches 90 percent of its full weight before age 4. If a child does not get enough protein during that critical period, the brain never does develop properly.

Research shows that *opaque-2*, ground up and used to make cornbread or tortillas, has the same nutritional value with respect to protein as skim milk. To a child in Guatemala, however, the milk is not available but corn is.

A major problem faces corn breeders, however, in developing varieties adapted to other nations. Adaptability to local soils and climate and disease resistance may require years of intensive breeding work. Much of this will have to be done by the countries themselves, although several U.S. agencies have already started to lend assistance. It can be assumed that, as *opaque-2* development and utilization keep progressing in the United States, some beneficial spinoff will occur in other countries too.

Direct use of *opaque-2* corn for human food products here in the United States is still in the speculation stage. A few food companies are known to be working on high-protein corn products, and when and if they are successful, the American public will undoubtedly be thoroughly informed. One cannot deny the fact that—despite affluence in our own nation—certain segments of our population need to improve their diet patterns. *Opaque-2* corn may well contribute directly to this need—certainly in an indirect fashion through the use of the high-protein

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corn in the rations of certain meat-producing animals.

Livestock Feeding

CONVERSION of *opaque-2* protein to animal protein by feeding it to monogastric animals (swine and poultry) will probably constitute the greatest utilization of the new corn. Unlike ruminants—cattle, sheep, and goats—swine and poultry cannot manufacture their own amino acid requirements and therefore, must depend on their rations to supply these needs. Hogs, for example, need a high level of lysine, which is ordinarily supplied by soybean-meal supplements. Feeding trials already show that hogs fed high-lysine corn require considerably less protein supplement.

Because high-lysine corn is expected to find its greatest use in swine rations, economists have selected this aspect of the livestock economy to determine the possible effects of high-lysine corn on the hog enterprise. Results of the study, which appear in adapted form under the following topic heading, were first published in *Economic and Marketing Information for Indiana Farmers* on May 31, 1968. Author of the report is A. Gene Nelson, Dept. of Agricultural Economics, Purdue University.

Potential Effects on the Hog Economy

TO determine the possible effects of reduced feed costs—due to high-lysine corn—on annual hog marketings and hog prices, supply and demand relationships were developed which provide that (1) current hog supply depends upon the price producers expected to receive when plans were formulated, (2) current hog price is determined by the available supply, and (3) plans cannot be changed during the production period once commitments are made.

The price and number of hogs marketed are determined by the balancing of factors affecting the supply of and demand for hogs. On the supply side, major factors affecting the number of hogs produced are expected levels of hog prices, feed costs, and cattle prices. On the demand side, important factors influencing the price of hogs are the number of hogs marketed and the value of pork products. The value of pork products, in turn, depends upon the consumption of beef and poultry, disposable personal income, and the size of the population.

Yield Assumptions.—The effects of high-lysine corn on the price and number of hogs marketed are estimated under different assumed levels of corn yields. The resultant savings in the cost of hog feed will depend upon the yields that can be achieved with high-lysine corn. As its production cost per acre is not expected to be different from regular corn, the yield of high-lysine corn relative to regular corn will determine the price at which it will be competitive from a production standpoint.

Depending upon the price of high-lysine corn, the formulation of hog feed rations would be adjusted. As the high-lysine corn price declines, more high-lysine and less regular corn would be fed. Also, less soybean meal would be fed. Because of the decreased demand for soybean meal, its price would decrease. Considering these factors, linear programming is used to calculate the savings in hog feed costs under five assumed levels of high-lysine corn yields.

The Results.—Estimated changes in the price and number of hogs marketed after the swine industry has had time to adjust to the feeding of high-hysine corn are presented in table 1.

The analysis indicates that high-lysine corn yields must be at least 94 percent of normal corn yields, or hog producers will achieve no savings in feed costs. For yields below 94 percent of normal, high-lysine corn could not be produced at a price that would make it an economical substitute for regular corn and soybean meal in swine rations. The hog economy would not be affected.

With high-lysine corn yields at 94 percent of regular corn yields, hog producers could reduce their feed cost by about 3.6 percent. In this situation, the estimates derived from the economic model are that hog producers would market 430,000 more hogs and the hog price per hundredweight would be 27 cents lower.

For high-lysine corn yields at 96 percent of normal corn yields, the results are not much different. The estimates are that the hog price would be 33 cents lower and that 533,000 more hogs would be marketed as a result of a 4.5 percent savings in hog feed cost.

However, with high-lysine corn yields at 98 percent of regular corn yields, the savings in hog feed costs would be 7.1 percent. In this situation the estimated decrease in hog price is 53 cents per hundredweight and the estimated increase in marketings is 850,000 head.

If high-lysine corn should yield at a level equal to ordinary corn, the savings in feed cost would be 8.8 percent. Under this last assumption, the estimates are that hog prices would decrease by 66 cents and marketings would increase by 1.05 million.

Conclusion.—The analysis indicates that if the yield of high-lysine corn is at least 94 percent of normal corn yields, more hogs will be produced and sold at a lower price. Who will benefit from this recent discovery of agricultural science? Because of the lag in adjustment, those hog producers who are early users of high-lysine corn will benefit from extra income until competition forces profits back to normal. However, insofar as the marketing institutions pass the savings along, the ultimate beneficiary will be the pork consumer.

TABLE 1.—*Changes in hog prices and annual hog marketings under various high-lysine corn yield assumptions*

High-lysine corn yield (percent of normal)	Change in—	
	Hog price ($ per cwt.)	Hog marketings (1,000's)
less than 94	[1]	[1]
94	−0.27	+430
96	−.33	+533
98	−.53	+850
100	−.66	+1,050

[1] No effect.

Other Possible Effects

SINCE high-lysine corn is also expected to be utilized in the poultry industry, some effect is also likely to occur in that aspect of the agricultural economy. As of now, no studies similar to that of the hog economy analysis have been made. Reduction of even one-half cent a pound on the production cost of poultry would make the feeding of high-lysine corn attractive to producers. Results from any conversions by producers will be watched closely.

Widespread use of high-lysine corn in livestock and poultry feeding is generally expected to cut into the consumption of soybean meal supplements. What effect this change would have on soybean production is purely guesswork at present. Economists do foresee a possible need for grain elevator operators and feed-mixing companies to substantially change their operational methods when and if a sizeable number of farmers begin switching to *opaque-2*.

Ironically, another research effort now going on may eventually serve to dampen the impact of high-lysine corn: The search for ways to economically produce synthetic amino acids. In the final analysis, costs will be the determining factor.[1] But regardless of the ultimate source of protein supplements, *opaque-2* corn is not likely to be put on the shelf as an agronomic oddity. Some payoff seems certain; a full realization of the magnitude of its development will sooner or later materialize.

[1] In reviewing this staff-written article, Dr. E. T. Mertz, Purdue, offered the following comment: "Synthetic amino acids may prove quite useful for cereals other than high lysine corn. However, assuming no yield reduction, the *opaque-2* corn plant can produce its extra endosperm lysine and tryptophan for approximately 2 cents a pound. It is doubtful that any industrial process can equal this low cost of production."

The Great Debate of 1905

AN entomologist in 1905, regardless of his preferences, was more likely than not to find himself involved in the greatest debate of the year—the California wash vs. the Oregon wash.

These "washes" were insecticide sprays developed chiefly to fight San Jose scale and similar pests of fruit trees. The California wash—so called because it originated in that State and was recommended by California entomologists—was a mixture of lime, sulphur, salt, and water. The Oregon wash was the same except copper sulphate was substituted for the salt. Because of widely varying claims, many experiment stations that year attempted to settle the issue once and for all by conducting tests.

Entomologists at the Connecticut (New Haven) Station announced that the Oregon wash was inferior to the California wash because it lost much of its effectiveness after a rain. In contrast, entomologists at the Storrs (Conn.) Station said the Oregon wash was superior. Boiling the mixture 30 to 45 minutes, they discovered, helped to dissolve the sulphur.

Delaware gave the nod to the California wash, but said a boiling time of 15 minutes was sufficient. Mississippi said a much longer boiling time was necessary.

The Illinois Station reported fairly good results with both washes, then recommended the Oregon wash. Maryland recommended the California wash, but noted that adding salt made little difference.

Despite favorable results with the California wash at the New Jersey Station, fruit growers of that State reported no success in using it, and the station finally recommended use of petroleum mixtures.

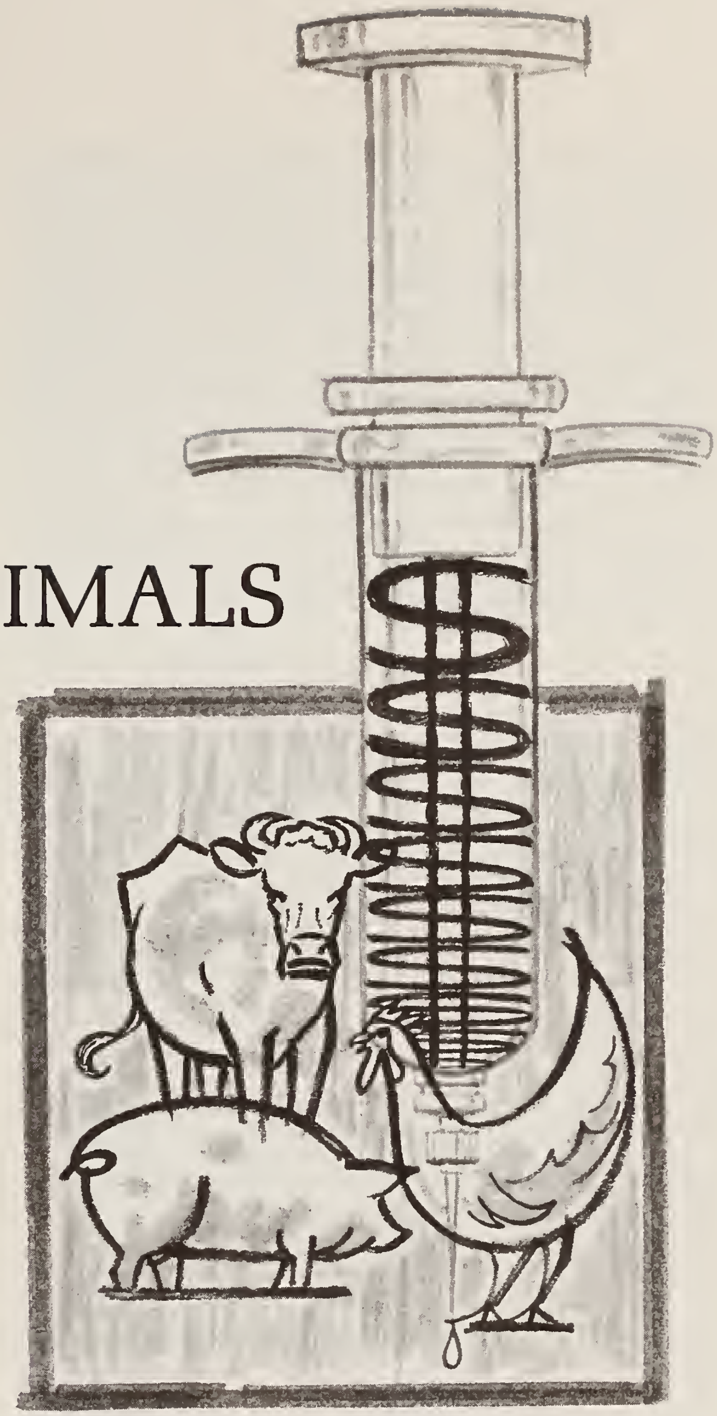
New York termed the California wash "a very effective insecticide as well as having fungicidal effects." Ohio saw little difference in either wash, but recommended boiling mixtures for 1 hour.

The Washington Experiment Station announced that the salt in the California wash was a useless ingredient and that a cold wash was just as effective as a hot one. In attempting to settle the salt controversy, California ran further tests and found, much to their dismay, that the salt, indeed, made little difference. Their official bulletin, however, stated that California entomologists "do not feel prepared to recommend the disuse of salt in the wash."

The great debate apparently ended in a draw, for for the 1905 Report of the Office of Experiment Stations "warmly recommended" both washes, but added that the California wash was less harmful to dormant trees and noted with satisfaction that its use was rapidly expanding in all States.

BREEDING Disease-Resistant DOMESTIC ANIMALS

F B. HUTT



DURING the past four decades, breeders of domestic animals have made remarkable progress in getting more eggs per hen, more milk per cow, and faster growth to market weight in broilers, beef cattle and bacon hogs. On the other hand, the high productivity now possible is attained only when the animals are kept reasonably free of disease, and the costs of the drugs, vaccines, antibiotics, or isolation necessary to maintain them in that desirable state are now so great that in many cases little margin of profit is left for the producer.

In every flock or herd stricken with disease, one can usually find some animals that are affected very little or not at all. Similarly, in our own species, long before there were vaccines against poliomyelitis, most of us were exposed to that disease (without knowing it) but only a very few were seriously stricken. If some animals can resist disease, why not multiply their kind and make the whole flock or herd resistant?

Some of the reasons why animal breeders and veterinarians have almost completely ignored the possibility of breeding disease-resistant animals are here considered, along with a few ideas that may help to counteract the objections most commonly raised whenever the feasibility of genetic control of disease is suggested.

Disease Resistant Plants

BEFORE pursuing that theme any further, let us consider briefly, for purposes of contrast, the remarkable accomplishments of the plant breeders and plant pathologists. By uniting their efforts, they have given us, in grains and grasses, in vegetables, and in fruits, modern varieties that combine yield, desirable market qualities and genetic resistance to disease. The net result has been a vast increase in the world's food supply, and, for many a farmer, a livelihood that would not have been possible without those same varieties. Evidence that the breeding of resistant varieties is still going on can usually be found by thumbing through the pages of any good farm magazine. From time to time, most such publications report on new plant varieties resistant to some wilt, blight, mildew, leaf spot, rust, or insect which earlier had been difficult to control.

Perhaps the best example of the economic importance of genetic resistance to disease in plants is that of wheat varieties now resistant to the stem-rust which once devastated the spring-wheat areas

of the United States and Canada. Their development has not been easy. As more and more biological races of the rust fungus became recognized, new genes for resistance to them were utilized by the plant breeders and combined with essential qualities like high yield, stiff straw, and good baking qualities to produce acceptable new varieties that could withstand the rust. These, in turn, now ensure not only an ample supply of bread for the people of North America, but also the shiploads of surplus wheat that have been sent so regularly to over-populated India and elsewhere.

Limitations on Some Methods of Control

It should be made clear that no geneticist in the field of animal science is likely to advocate breeding for resistance to any disease that can be adequately controlled by other means at a cost that is not prohibitive. There are some diseases, however, against which the orthodox sanitation and carbolic acid are ineffective, and for which effective vaccines are not available. The leucosis complex in the fowl, as it was known for some 30 years, is a good example. Now, when that complex has been split into two separate diseases—Marek's disease (neurolymphomatosis) and leucosis—there is still no vaccine, nor is the carbolic acid any more effective against either. We shall return to Marek's disease later; suffice it here to say only that (1) isolation of newly hatched chicks will provide a measure of control for both Marek's disease and leucosis that is commensurate with the degree of isolation, (2) complete isolation is expensive and difficult to attain, and (3) the efficacy of genetic control has been amply demonstrated (*13*).[1]

In other cases—for example, mastitis in cattle—effective control can be attained by the constant use of antibiotics, but these are expensive, and, moreover, public health officials are now concerned about having the public dosed with antibiotics in the milk.

Vaccines are not always the answer. In Britain, where over 400,000 animals were slaughtered in 1967–68 to control an outbreak of foot-and-mouth disease, there is a laboratory (Pirbright) at which vaccines effective against that disease are made. These are sent abroad to countries which try to control foot-and-mouth disease by vaccination, but they are not used in Britain. Authorities there believe that attempts to control foot-and-mouth disease would cost about $48 million annually (*21*), and that eradication of the disease by slaughter is cheaper.

Problems in Genetic Control

WHY is there currently so little interest in breeding disease-resistant animals?

To begin with, it is axiomatic that there is no point in attempting to do so until evidence has been adduced that there is genetic variation in resistance to the particular disease under consideration. About 10 years ago, when the data then available were reviewed (*10*), it was clear that for every disease of domestic animals which had been adequately investigated for evidence of genetic resistance, such evidence had been found. It is reasonable to assume that genetic resistance is available for utilization against every infectious disease or parasite in any species.

More often than not, genetic resistance to disease is polygenic—not a simple Mendelian dominant or recessive trait. Breeding for polygenic characters is a slow process, and progeny-testing, which is the most effective procedure, is difficult when sires and dams must be kept until the resistance of their offspring can be tested. This is no problem with species in which the interval between generations is short, as in chicken or pigs, but it is more serious with larger animals.

It should be made clear, also, that genetic resistance to one disease is usually quite independent of genetic resistance to others, hence there is little hope of establishing quickly some superrace that is genetically resistant to all disease. In the fowl, breeds comparatively resistant to *Salmonella pullorum* are also resistant to *S. gallinarum,* and there is some evidence (unpublished) that strains resistant to Newcastle disease are also resistant to other respiratory diseases. In that same species, Cole (*4*) found three strains of Leghorns at Cornell University to differ significantly in mortality from blue-comb disease (later dubbed avian monocytosis), but strain S, which was highly resistant to bluecomb, proved to be extremely susceptible to leucosis (*12*). Strains C and K were equally resistant to leucosis, but Strain C, which Cole had found to be less resistant than K to blue-comb, was later found to be more resistant than K to Newcastle disease (*6*). Similarly,

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[1] Italic numbers in parentheses refer to Literature Cited, p. 18.

Gowen (*9*) found resistance to one pathogen in mice to be quite independent of resistance to two others.

While such independence of resistance complicates the problem of attaining genetic control of diseases, it does not make that prospect hopeless. A review by Walter (*20*) tells how resistance to diseases of the tomato has been used in various parts of the world to develop varieties which permit growers to cope with the particular diseases most serious in their areas, and that efforts to combine such resistances are now under way in several laboratories in the United States and in 10 other countries.

The greatest difficulty preventing the utilization of genetic resistance to disease in animals is that (in most cases) identification of the resistant animals so necessary for breeding resistant strains can be made only in stock that is exposed to the particular disease under study. Only by exposure of some kind can one discover which animals can thrive in the presence of the pathogen, and which can not. Any idea of deliberately exposing animals to disease is "heretical" to the veterinarians, on whom the animal industry relies for control of diseases. Veterinarians are trained to eradicate disease—not to let animals live with it. Most stockmen are more interested in immediate profits than in breeding good stock for posterity, and probably feel the same way.

Sometimes a disease will not stay eradicated. It may be controlled temporarily in single animals, or even in an entire flock or herd; but, because the organisms responsible cannot be banished from the world, it may return again soon after treatment is stopped. Mastitis in dairy cattle is a good example. Not infrequently, disease strikes without warning, too late for the effective administration of vaccines, sulpha drugs, or antibiotics. When this happens, resistant animals can often be identified before the disease has run its course, or is brought under control. In pedigreed flocks and herds it may be possible under such circumstances to recognize not only resistant individuals, but also resistant families. These in turn reveal which sires and dams should be reused to beget resistant offspring.

Inevitable Selection For Resistance

WILD animals stricken by diseases to which they have not previously been exposed are, naturally, unable to receive the protection of vaccines, drugs, and antibiotics; so they must, perforce, utilize a mechanism for defense that is usually denied to domestic animals. In the long run that defense sometimes proves to be more effective than any other. It is simply the survival of the fittest and their multiplication to breed a resistant stock. Even in the short span of a human lifetime, we have watched houseflies become resistant to DDT, and have seen the hardy oysters of Prince Edward Island vanquish the mysterious Malpeque disease that once nearly wiped them out. Such breeding of resistant stock is not a procedure restricted to invertebrate animals. In Australia and elsewhere, the rabbits once so susceptible to myxomatosis are demonstrating that they too can breed resistant strains. In Africa, assorted ungulates of all sizes, which, under continous expose, have developed resistance to the trypanosomes carried by tsetse flies, provide a natural reservoir of infection which makes difficult the task of trying to protect domestic cattle against trypanosomiasis by other means.

A good example of selection for resistance to disease that was literally forced on the breeder was provided when Fredeen (*7*) developed the Lacombe pigs in Alberta. The herd in which this new breed was formed was riddled with atrophic rhinitis. He was advised to slaughter the entire herd, to disinfect the premises, and to leave them vacant for some months. As such action would have delayed part of his research program for several years, it was decided to make the pigs live with the disease and to select, among other objectives, for ability to resist atrophic rhinitis. As a result, the disease gradually disappeared. After four years without any sign of rhinitis, the Lacombe breed was released to the public. Although no critical tests have been made, reports from private breeders indicated that the breed seemed to excel others in resistance to rhinitis.

A somewhat similar history may be responsible for the superior resistance of the Cornell C strain of Leghorns to respiratory disease. During its formative years in 1934 and 1935, the flock suffered heavy losses from laryngotracheitis. They were not vaccinated or otherwise protected, but the most resistant families were used to develop Strain C. By 1936 the disease had disappeared and it has not recurred in Strain C, although other birds on the same premises have been affected. Resistance of the

C Leghorns to laryngotracheitis has not been critically tested, but their superior resistance to one respiratory affliction (Newcastle disease) has been demonstrated (*6*). Evidence is good that it applies also to other respiratory diseases.

Indicators of Genetic Resistance

A WAY in which genetic resistance to disease can sometimes be utilized without offense to veterinary orthodoxy was suggested a few years ago (*12, 13*). All that is necessary is to find some genetic variation in form or function that is consistently associated with resistance to some specific disease. With such an indicator, one could breed resistant animals without exposing them to the disease. At first thought the possibility of finding indicators of this sort might appear very remote, but two of them have already been conclusively demonstrated and a promising third awaits confirmation. These are enough to suggest that more such indicators might be found if a search were made for them.

Cancer eye in Hereford cattle.—The simplest kind of indicator is one that can be easily seen. A good example is the ring of pigment around the eye which protects Hereford cattle from developing carcinoma of the eye, or "cancer eye", which is a common affliction in animals of that breed more than 4 years old in areas subject to intense sunlight. As Anderson (*2*) has shown, there are genetic differences in susceptibility to the condition, but selection against a trait not evident for at least 4 years would be a very slow process. Fortunately there is an indicator of resistance by which such selection can be greatly accelerated. It is visible when the calves are only 3 months old, or less.

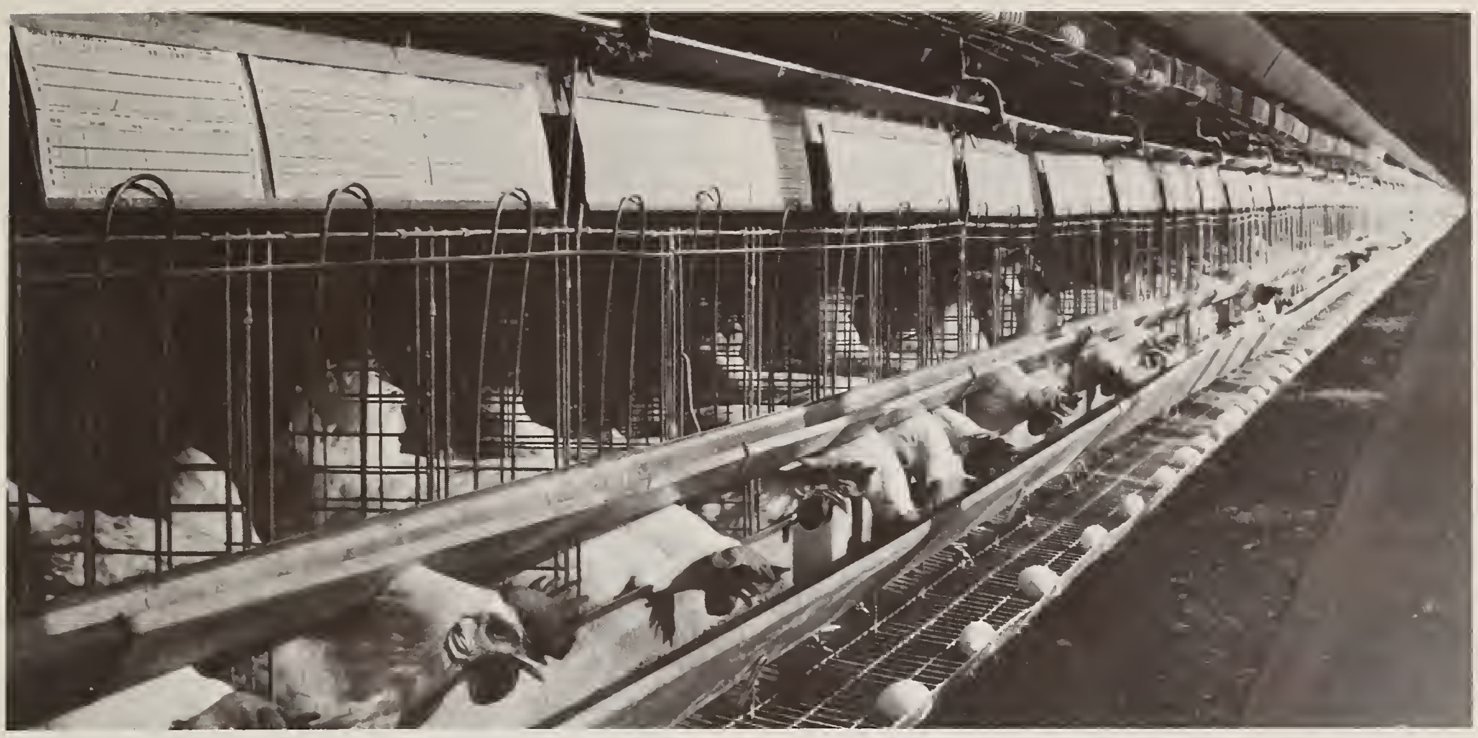
As Bonsma (*3*), French (*8*), and Vogt *et al.* (*19*) have shown, the incidence and severity of cancer eye is negatively correlated with the degree of pigmentation of the eyelids. Animals that have a ring of pigment at least half-an-inch wide around the eye are practically immune. Since the pigmentation of the eyelids is heritable, as French and Vogt *et al.* have shown, it serves as an ideal indicator—one which should make breeding for resistance to cancer eye a comparatively simple process.

An indicator of resistance to pullorum disease.—From a search conducted over a period of 20 years, it was concluded that genetic resistance of chicks to infection by *Salmonella pullorum* is associated with superior control of the chick's thermoregulatory mechanism. The story of that search was summarized earlier (*10*). Efficient control of body temperature causes resistant chicks to develop and sustain fever temperatures when infected, but it can be measured in chicks not infected by the rate at which body temperature is raised after hatching from the 102° to 103° F of day-old chicks to the 105°–107° that is normal in adult birds. This change is part of the normal transition from the cold-blooded state of the incubating embryo to the warm-blooded, air-breathing state of the 10-day-old chick. Although the complete rise in temperature takes 10 days, most of it is attained in the first 6; and, from the average of 3 recordings at spaced intervals during those first 6 days, one can distinguish the chicks that are able to raise their temperatures quickly from those that cannot do so.

For a critical test of the possible usefulness of such an indicator to breed resistant stock in uninfected animals, two lines of birds were differentiated by two generations of selection for high or low chick temperatures at 1 to 6 days of age (*14*). In the second generation, average temperature in one line was 0.59° F higher than in the other. When samples of the two strains were experimentally inoculated with *S. pullorum,* the high-temperature line proved to be consistently more resistant than the other. On the lightest dosage, mortality to 3 weeks of age was 40.7 percent in the low-temperature line, but only 8.6 percent in the high-temperature line. Clearly, the indicator was effective.

As pullorum disease has been controlled by elimination of infected carriers, this indicator has, so far, not been needed. It remains to be seen to what extent facile control of the thermoregulatory system might prove useful as an indicator of resistance to other diseases. The important points established by these studies with pullorum disease are that (1) an indicator of genetic resistance was sought and found, and (2) the efficacy was demonstrated of using that indicator to breed disease-resistant animals without exposing them to disease.

An indicator of resistance to mastitis in cattle.—Available evidence from various sources that cattle differ genetically in resistance to mastitis was reviewed earlier (*10*). It was subsequently pointed out (*11, 13*) that in three separate investigations in two countries the incidence of mastitis was reduced



at least one-third by a single generation of mass selection on the dam's side only. In spite of such encouraging evidence, there has been no rush to breed cattle resistant to mastitis. The attitude of the disease controllers who continue their attempts to eradicate the assorted bacteria which can cause mastitis is still much like that of the football fans who, from the stands, exhort their embattled heroes to "Hit 'em again, hit 'em again, HARDER, HARDER!" While such tactics may be temporarily successful, it seems possible that the bacteria, which have in the past demonstrated remarkable resilience to just such onslaughts, and have so often and so quickly developed resistant strains, may (unheard) be rallying their forces with the refrain "We shall overcome."

One problem in breeding for resistance to mastitis is that susceptibility increases with age and is seldom evident in the first lactation. Rendel and Sundberg (*17*), whose studies confirmed the previous evidence of genetic resistance, concluded that it was scarcely practicable to breed resistant stock because of the difficulty of progeny-testing sires for a condition that could not be dependably measured in the first lactation. While that is undoubtedly correct, the situation would be entirely different if some indicator could be found which would distinguish resistant cows from susceptible ones either in that first lactation or before.

A possibility that just such an indicator might be forthcoming is seen in the studies of Adams and Rickard (*1*) who tested *in vitro* the bactericidal powers of fatty, sebum-like material from the teat canals of animals differing in susceptibility to *Streptococcus agalactiae* and determined by chromatography the composition thereof with respect to fatty acids. Material from quarters resistant to artificial infection had higher content of myristic, palmitoleic and linoleic acids than susceptible quarters, and all of these fatty acids proved to have good bactericidal potency. In contrast, susceptible quarters had more palmitic acid than resistant ones, and this fatty acid showed less bactericidal potency than the three others listed in the previous sentence.

It would seem that this promising lead should be followed. Adams and Rickard found that they could determine the fatty acids as well in young, 2-year-old heifers as in older animals. If these results are confirmed, and if the fatty-acid composition can be used as an indicator of resistance to mastitis caused either by *Str. agalactiae* or by other bacteria, the ability to identify resistant females before lactation would make it somewhat easier to breed for resistance to mastitis than to breed for higher yields of milk or butterfat. The possibility that skin secretions from bulls might provide similar material for analysis is worth testing, but there is little point in pursuing such speculation here.

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Marek's Disease and Sampling

FOR coping against Marek's disease in the fowl, a procedure recently developed now permits more rapid progress in breeding disease-resistant stock than ever before. It is the deliberate inoculation (in an isolated laboratory) of samples of strains and families with a standard dose of the pathogen at a level of dosage strong enough to reveal quickly which animals are resistant and which susceptible. Details are given by Cole (*5*), who used the procedure to differentiate strains of White Leghorns that differed greatly in resistance to Marek's disease. This condition, once designated fowl paralysis or neurolymphomatosis, is now named after the Hungarian pathologist who first recognized it to be a specific disease. It has since been found to be caused by a virus of which there may be several different strains.

Even when breeders were dependent upon natural exposure, it was possible to breed strains resistant or susceptible to this disease (*12, 13*), but it takes years to do so. Cole used the so-called JM virus, a potent pathogen which had been discovered by Sevoian of the Massachusetts Agricultural Experiment Station and to which the Cornell S strain of Leghorns, long bred for susceptibility to leucosis, had proven extremely susceptible. Starting with a stock not previously selected for resistance to leucosis, he tested 25 sire families for resistance to the JM virus as measured by death or lesions at autopsy up to 8 weeks after intraperitoneal inoculation. Sires and dams (none inoculated) that produced the most resistant families were used to start one line; those yielding the most susceptible started another. Thereafter, adequate samples of each line were tested by inoculation, but the lines were reproduced from uninoculated siblings of the best families that had been revealed by the inoculated samples. In the second generation, among over 1,200 chicks tested in each strain, only 12.9 percent of the resistant line had died of the disease or showed lesions of it at 8 weeks, but for the susceptible line the corresponding figure was 90.7 percent.

It should be emphasized that in Cole's studies every chick inoculated was isolated; all inoculated chicks that did not die were destroyed; and only uninfected birds were used in subsequent matings to produce the two lines. By subjecting every chick under test to a dosage far more severe than that encountered with natural exposure in the field, differentiation of resistant and susceptible families was improved, and the period under test was shortened. Samples thus tested provided such a good guide to the selection of breeding stock that in two generations a greater differentiation of resistant and susceptible strains was attained than any that could be made in 10 years of testing with only natural exposure to a less virulent pathogen.

Cole found that when uninoculated chicks were kept in contact with those inoculated, mortality and lesions were about the same in both groups. As the contact controls must have become infected through natural channels, without having any of their defense mechanisms bypassed as is inevitable with intraperitoneal inoculation, it seemed probable that either method of exposure might reveal which birds could best resist natural exposure to Marek's disease in the field. Evidence that they do so has come from various sources. It was also found that male chicks were as good as females for the laboratory tests, whereas previously the greater resistance of males than of females had, among other considerations, made use of the former less satisfactory in field tests.

With all these advantages, it is not surprising that Cole's procedure for breeding fowls resistant to Marek's disease is now being used by several of the world's large-scale poultry breeders. Whether or not such testing of samples for resistance to disease is feasible with bigger animals remains to be seen.

Genetic Resistance to Parasites

WHILE enough is known about genetic resistance of crop plants to insects to warrant a book on that subject (*15*), comparatively little study has been made of genetic resistance in animals to the parasites that beset them within and without. The resistance of zebu cattle to ticks and tick-borne diseases has been utilized in different parts of the world, and some studies have been made to find the anatomical or physiological basis for that resistance. At this writing there does not seem to be agreement on that score. Perhaps the answer would come faster if more animals could be found for study like the wonderful Honduran cow which Ulloa and de Alba (*18*) found able to keep herself free of ticks for nine months in a tick-infested environment.

At any rate, as part of a program to obtain a maximum control of pests with an indispensable minimum of dangerous pesticides, it would seem highly

desirable to utilize genetic resistance to ectoparasites of any kind. Too little is known about the possibilities in that direction, and further study seems highly desirable, particularly with parasites that are vectors of pathogenic protozoa, Rickettsias and other organisms.

With respect to internal parasites, while there is ample evidence of genetic resistance to certain protozoa in cattle, to coccidia in chickens, and to nematode worms in sheep and goats, strains or breeds deliberately bred by man to combine such resistance with other characters of economic value are practically unknown. The Bonsmara cattle bred in the Transvaal to utilize the resistance of Africander (zebu) cattle to ticks are an exception.

By simple natural selection, Nature made the Romney Marsh sheep comparatively resistant to trichostrongyle worms and the N'Dama cattle of West Africa resistant to trypanosomiasis. These accomplishments have been discussed elsewhere (*12*). It is to be hoped that eventually man, by progeny testing, will obtain results far faster than is possible with Nature's mass selection, and will do as well or better against other parasites. Genetic resistance is not likely to make use of drugs entirely unnecessary for the control of parasites, but careful use of both kinds of control might retard the process by which ever-stronger drugs breed ever-stronger parasites.

What Diseases?

IT is not for this writer to say for what diseases of domestic animals genetic control should now be sought. A safe generalization is that it should be tried with any disease for which other methods of control are still inadequate. Perhaps foot-and-mouth disease is as good an example as any.

One can understand that watchful officials will stamp out foot-and-mouth disease in any country now free of it and where the disease has occurred only rarely. This applies to the United States and Canada, also to Australia, which, being somewhat isolated, has had no foot-and-mouth disease since 1872.

In some other parts of the world, where the disease is enzootic or reappears at intervals of a few years, the usual control is by vaccines, or by slaughter to prevent its spread, or by a combination of both. The recent outbreak in Britain was only the latest of six outbreaks there in the last 45 years (*21*). Although it has now been stamped out, there is no assurance that some gull flying across the Channel from the continent will not bring it in again next year.

In countries subject to periodic or continuous trouble with foot-and-mouth disease, it would seem logical to explore the possibility of utilizing genetic resistance. We are told that the disease kills only about 3 percent of infected cattle, but somewhat more in sheep and swine. Animals to which the disease is not fatal are said to become unthrifty, but how many, and for how long, is not clear. What seems certain is that with any disease causing so little mortality, there must be animals (perhaps 10 percent or more) at the other end of the range of a normal distribution which are affected very little or not at all. Such biologically superior animals perish with the rest in slaughtered herds, but Prat (*16*) reported that one completely resistant Charollais cow produced six similarly resistant descendants, three of which (when exposed) showed only mild symptoms for a few days, and all of which maintained normal milk production. While it would be easy to dismiss the record as an isolated case, any geneticist who has studied resistance to disease in pedigreed animals will recognize it as a straw that shows which way the wind blows. Further evidence of such genetic resistance to foot-and-mouth disease will undoubtedly be found when it is sought.

It is to be hoped that studies of the feasibility of genetic control of this disease will eventually be made in countries where exposure to it is inevitable. The fact that the U.S. Department of Agriculture is able to maintain on Plum Island an isolated laboratory for the study of foot-and-mouth disease suggests the hope that offshore islands might be similarly used by other countries, and that on some of them attempts will be made to breed resistant stock.

The fact that there are several variants of the virus causing foot-and-mouth disease presents no insuperable barrier. Another objection sometimes put forward is that genetic control means living with the disease, and that any country in which the disease is thus enzootic will lose its market for purebred stock elsewhere. Perhaps so, but when the day of enlightenment dawns, cattle breeders in countries where foot-and-mouth disease is inevitable may realize that the ability to beget progeny resistant to that disease is a better asset for a prospective herd sire than a pedigree sparkling with illustrious names at the Perth bull sales.

LITERATURE CITED

(*1*) ADAMS, E. W., AND RICKARD, C. G.
1963. THE ANTISTREPTOCOCCIC ACTIVITY OF BOVINE TEAT CANAL KERATIN. Amer. J. Vet. Res., 24: 122–135.

(2) ANDERSON, D. E.
1960. STUDIES ON BOVINE OCULAR SQUAMOUS CARCINOMA ("CANCER EYE"). V. Genetic aspects. J. Hered., 51: 51–58.

(3) BONSMA, J. C.
1949. BREEDING CATTLE EOR INCREASED ADAPTABILITY TO TROPICAL AND SUBTROPICAL ENVIRONMENTS. J. Agr. Sci., 39: 204–221+ Pl. 10–16.

(*4*) COLE, R. K.
1950. DIFFERENCES IN FAMILIAL INCIDENCE OF MORTALITY FROM "BLUE COMB" DISEASE. Poultry Sci., 29: 398–404.

(5) COLE, R. K.
1968. STUDIES ON GENETIC RESISTANCE TO MAREK'S DISEASE. Avian Diseases, 12: 9–28.

(6) COLE, R. K., AND HUTT, F. B.
1961. GENETIC DIFFERENCES IN RESISTANCE TO NEWCASTLE DISEASE. Avian Diseases, 5: 205–214.

(7) FREDEEN, H. T.
1963. GENETIC ASPECTS OF DISEASE RESISTANCE. Canad. Vet. J., 4: 219–233.

(*8*) FRENCH, G. T.
1959. A CLINICAL AND GENETIC STUDY OF EYE CANCER IN HEREFORD CATTLE. Austral. Vet. J., 35: 474–481.

(9) GOWEN, J. W.
1937. CONTRIBUTIONS OF GENETICS TO UNDERSTANDING OF ANIMAL DISEASE. J. Hered., 28: 232–240.

(*10*) HUTT, F. B.
1958. GENETIC RESISTANCE TO DISEASE IN DOMESTIC ANIMALS. Ithaca, N.Y.: Cornell University Press; London: Constable & Co., Ltd., XII + 198 pp.

(*11*) HUTT, F. B.
1961. IDENTIFICATION AND ELIMINATION OF DEFECTS IN ANIMALS. Germ Plasm Resources, Edited by R. E. Hodgson. Publication No. 66, Amer. Assoc. Adv. Sci., Washington, D.C., pp. 355–369.

(*12*) HUTT, F. B.
1964. ANIMAL GENETICS., New York: The Ronald Press Co., XIV + 1–546.

(*13*) HUTT, F. B.
1965. THE UTILIZATION OF GENETIC RESISTANCE TO DISEASES IN DOMESTIC ANIMALS. Genetics Today. Proc. XI Internat. Congress of Genetics, The Hague, 1963. Pergamon Press, Oxford, vol. 3: 775–783.

(*14*) HUTT, F. B. AND CRAWFORD, R. D.
1960. ON BREEDING CHICKS RESISTANT TO PULLORUM DISEASE WITHOUT EXPOSURE THERETO. Canadian J. Genetics and Cytol., 2: 357–370.

(*15*) PAINTER, R. H.
1952. INSECT RESISTANCE IN CROP PLANTS. New York, Macmillan Company. 520 pp.

(*16*) PRAT, J.
1952–53. SUR LA TRANSMISSION HÉRÉDITAIRE DE L'IMMUNITÉ NATURELLE CONTRE LA FIÈVRE APHTEUSE CHEZ, CERTAINS BOVINS. Bull. Soc. Sci. vét. Lyon, 54/55: 297–302.

(*17*) RENDEL, J., AND SUNDBERG, T.
1962. FACTORS INFLUENCING THE TYPE AND INCIDENCE OF MASTITIS IN SWEDISH DAIRY CATTLE. Acta Vet. Scand., 3: 13–32.

(*18*) ULLOA, G., AND DE ALBA, J.
1957. RESISTENCIA A LOS PARÁSITOS EXTERNOS EN ALGUNAS RAZAS DE BOVINOS. Turrialba, 7: 8–12.

(*19*) VOGT, D. W., ANDERSON, D. E., AND EASLEY, G. T.
1963. STUDIES ON BOVINE OCULAR SQUAMOUS CARCINOMA ("CANCER EYE"). XIV. HERITABILITIES, PHENOTYPIC CORRELATIONS, AND GENETIC CORRELATIONS INVOLVING CORNEOSCLERAL AND LID PIGMENTATION. J. Animal Sci., 22: 762–766.

(*20*) WALTER, J. M.
1967. HEREDITARY RESISTANCE TO DISEASE IN TOMATO. Annual Review of Phytopathology, 5: 131–162.

(*21*) WEST, G.
1967. FOOT-AND-MOUTH: IS THERE AN ANSWER? Illustr. London News. Dec. 2.

Alternatives and Consequences for PRESERVING THE FAMILY FARM

PAUL L. FARRIS

ONE of the vital issues facing farmers today is whether they can and should attempt to influence the future organization of farming and the determination of farm income. The structural changes sweeping through the food and fiber industries are disintegrating the family farm in ways not fully visible from trends in farm numbers and sizes. Farmers are losing their managerial independence, which is a fundamental loss from the standpoint of family farm agriculture.[1] Farm earnings are being influenced by forces and decisions which increasingly lie beyond the farmer's control.

Changing Structure of Farming

RAPID change alone in number and sizes of farms is an important cause of anxiety among farmers and disturbances in rural communities. The number of farms in the United States dropped from 4.1 million in 1959 to 3.25 million in 1966, which was a continuation of the long time downward trend. Most of the casualties were small commercial farms. The number in larger size groups increased. Farms with sales of $20,000 and over rose from 325,000 in 1959 to 527,000 in 1966. Farms in this size class—about 16 percent of the total number of farms in 1966—accounted for about two-thirds of the value of farm products sold in 1966, up from about half in 1959 (*14*).[2] They will account for higher proportions in the future as more small farms disappear and the total number of all farms continues to decline.

The advantages of large units are reflected in higher average per-farm earnings on large farms than on other farms. A special study of parity returns position of farmers prepared for Congress by the U.S. Department of Agriculture showed that in 1959, 1964, and 1966, farms with annual sales of $20,000 and over earned relatively higher returns per unit of labor and capital employed in farming than did smaller farms (*14*). This fact helps explain the intense competition among farmers for additional land. Many operators of small units recognize that they need to grow larger in order to obtain greater income.

[1] A family farm is generally defined as one in which (a) the entrepreneural functions are vested in the farm family, (b) the family furnishes most of the labor except for seasonal work or transitional changes in the family, and (c) the farm is large enough to employ resources of the farm family efficiently. Reference: *Family Farm Policy*, (Lit. Cited, Item 7).

This article was adapted from an address presented by the author at Farm Science Days, Purdue University, Lafayette, Ind. Jan. 9, 1968.

[2] Italic numbers in parentheses refer to Literature Cited, p. 26.

Yet the increasing share of business done by large farms has come primarily from greater numbers in large-size classes rather than that the large farms in existence have grown to massive size (*11*). When a family farm definition is based on a labor requirement of 1.5 to 2 man-years, not many production units are larger than family farms. And in most farming situations, studies relating cost per unit to size have generally shown that all the economies of size could be achieved by modern and fully mechanized 1-man or 2-man farms (*8*). In size of business, therefore, family farms dominate American agriculture; with current technology, they can continue to do so. Technology will not remain constant, but 10 or 20 years from now we will still probably count large numbers of family-size farms.

Loss of Managerial Independence

BUT how many or how few, while an interesting conjecture, is not the central issue. Entrepreneural functions—assumed to be vested in the farm family—are slipping out of the farmer's hands. Rising capital requirements and growing importance of purchased inputs ties the farmer closer to his suppliers and creditors. In producing some commodities, the farmer is subject to increasing degrees of managerial supervision from his suppliers and creditors. In selling, farmers are faced with increasing pressures and incentives to standardize product quality and to gear large and regular volumes of product supplies to particular market outlets. Various contractual arrangements are being used more widely, in which more and more management is being assumed by nonfarm firms. In some cases, the source of a farmer's production inputs and the market outlet for his product is the same firm, and this firm's field representatives watch closely over the farmer's shoulder throughout the production process.

A farmer's options in selling are being narrowed further by a reduced number of buyers and by disappearance of traditional open markets. Producers of most farm products in the past have had readily available to them markets in which prices, though subject to various kinds and degrees of imperfections, operated in a relatively impersonal manner. Such markets are fading from the scene. Many producers are finding it more and more desirable to have a specific sales outlet in sight before making production decisions. Without it, the market uncertainties are too great. And after production is undertaken, a producer is relatively dependent upon the party with whom he has made selling arrangements. Raw undifferentiated supplies of one farmer can easily substitute for those of another.

How much managerial independence has been lost by farmers varies widely among enterprises and areas of the country. The shift of entrepreneural functions off the farm has been greatest for poultry and some specialty crops. It appears to be occurring more rapidly for livestock than for most field crops. With increasing specialization, livestock production is becoming organizationally detached from feed production (*1*), and in some areas of the country is becoming highly industrialized. An important example is cattle feeding in the West. Farmers in the Midwest appear to have retained more of the management and risk-taking functions than farmers in other areas, but their traditional types of operations are being strongly challenged by integrated production-marketing systems in other sections.

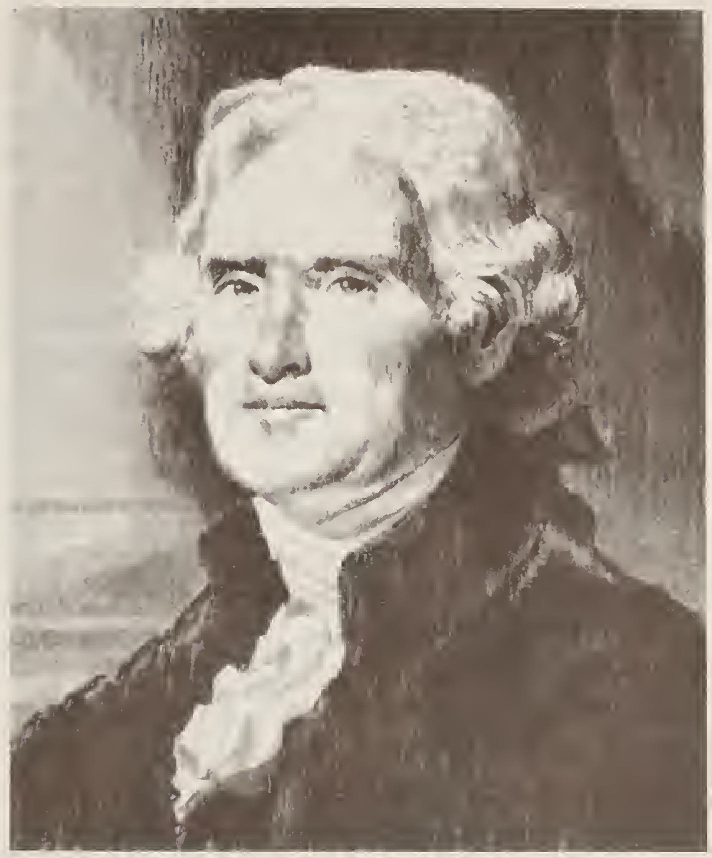
The real threat to the family farm, therefore, is the loss in managerial latitude and the prospect that even though the farmer continues to labor much as he has in the past, he will have lost much of his managerial independence, and with that, his cherished role in the agricultural economy.

Breimyer has observed that "years ago, the institutional character of agriculture was primarily determined by the rules of land ownership, the terms of tenure, the laws of inheritance. Today, it is likely to be affected also by the farm's relation to its supplying and buying market." (*2*) The farmer's business is becoming increasingly interwoven with the business of the marketing system, and the farmer is finding himself in an environment where decisions in the nonfarm sector control his managerial options and establish his earnings.

Other Characteristics of Agriculture

OTHER well-known characteristics of agriculture intensify changes in numbers, sizes, and managerial independence of farmers as well as bring repeated pressures on earnings. Uncoordinated output frequently results in supplies greater than the market will absorb without sharp declines in prices. Quantities taken by the domestic market are little influenced by income or price changes, and foreign

markets are often unpredictable. Relatively high fixed costs in agriculture cause farmers to keep on producing even when prices decline. The onrush of technology brings constant pressure for adjustment. With purchased inputs growing in importance and consumption expenses rising as farmers obtain an increasing share of family living items from the market, many farmers have become increasingly vulnerable to farm income fluctuations and to the cost-price squeeze from declining farm prices and rising nonfarm prices in an inflationary economy.



POLICY ALTERNATIVES

WE assume, in looking at policy alternatives, that the future organizational structure of farming is not at this time predetermined. More large farms will appear, and more tightly coordinated production-marketing systems seem certain to come. But food and fiber can be produced at low cost under any one of several organizational arrangements. The kind that emerge, who will be in control, and the amount of managerial freedom retained by farmers will be determined by actions of farmers, by actions of those who deal with farmers, by visions and motivations of persons in leadership positions, and by public policies of the nation.

Four broad policy directions appear to be realistic alternatives. Each may have a place. The amount of emphasis given to each will depend on individual situations and on the support each receives.

Open Competitive Market Approach

THIS approach sounds highly appealing, and we all support it in principle. Agricultural price and income programs would be gradually eliminated except for standby emergency measures. But in addition, market exchange processes would be made to work more effectively and used more widely in transferring goods from one stage to another from farmer to consumer. Markets would be restructured to increase the number of buyers of farm products and sellers of farm supplies. Where firms are large in relation to the market, they would be split up. Vertical integration and contract farming could exist provided genuine alternatives remain available. Facilitating services such as market news, grading and standardization programs, and information about prospective market supplies would be expanded so that the large number of buyers and sellers participating in rejuvenated open markets could do so intelligently and on equal bases with each other. Information about contract terms and other potential successors of ordinary spot prices would be gathered and made available. Regulatory agencies, such as the Federal Trade Commission and the Packers and Stockyards Administration, would be supported with adequate resources so they could guard against competitive abuses.

Critics of this approach would probably point out that it would be difficult to accomplish politically. It would be strongly resisted by processors, distributors and farm suppliers, and probably by farmers. It would mean prescribing for the farm economy what does not prevail in the nonfarm economy—and which would be even more difficult to implement in the more industrialized sectors. Galbraith points out, for example, that the future of the industrial system is not even discussed because such firms as General Motors, General Electric, and U.S. Steel are viewed as an ultimate achievement. But agriculture is assumed to be in the course of change and its future is subject to debate (*5*).

Prospects for Change Under Current Policies

If present policies remain as they are, organizational changes in process will undoubtedly continue their present course. We will probably see substantial further vertical integration both through direct ownership and by contract. Some open markets will dry up and prices they generate will become less and less representative of general supply and demand conditions. The variability among buyers and sellers in the quality and amount of market knowledge they have available to make trading decisions, and consequently in their negotiating skill, may widen. Although advancing technology in communications has facilitated rapid dissemination of information which has become available, the information which is readily available may become incresingly inadequate and the cost and effort required to become informed in order to buy or sell skillfully is likely to remain substantial.

Management will likely continue to gravitate from the hands of farmers to those of processors and suppliers and the farmer's role reduced further toward that of a laborer. It seems unlikely that integrating companies will completely take over the production of food and fiber by owning the land and capital and hiring the labor because these companies can earn more with their resources in other uses. Also, integrating companies can use contracts to shift the incidence of production costs, such as social security, workmen's compensation, and possibly union wages, which would likely come with complete ownership of land and other production resources.

Some examples of land purchase by outsiders because of tax advantages have been cited, but relatively free entry into agriculture draws capital and labor of farmers in quantity great enough to keep output pressing on available markets and downward pressure on prices. Farmers then, as Paarlberg observes, are willing to offer their labor for a low return. "This they do because, once they are committed to agriculture, they have few good alternatives." (*12*)

Although rising capital requirements of modern farming and limited availability of land deter entry by some potential farmers and tend to concentrate land holdings among the more successful, this trend seems not to dampen the drive of farmers to expand production. It may, in fact, do the opposite.

A subsidy program which would substantially increase farm earnings and maintain them at a high level would tend to attract more nonfarm capital into agricultural production. It would also tend to widen the difference in earnings among individual farmers and further increase land prices.

However, farmers do have options even without change in legislation or public policy. An important one is through cooperatives. The National Commission on Food Marketing believed that "farmers do not yet fully appreciate the importance of cooperative action in marketing their products." (*10*)

Cooperatives might become more aggressive in some areas where they have already demonstrated notable achievements, such as the purchase of farm supplies. Also bargaining efforts might be increased. Willard F. Mueller, Director of the Bureau of Economics of the Federal Trade Commission, recently told cooperative leaders that "There are intractable positions of market power that do not yield readily to antitrust remedy. Here is where agricultural and consumer cooperatives can perform a key role in making competition work effectively." (*9*) Where considerable internal group discipline is possible, the group representing farmers can often improve terms of trade for the group. The potential for improvement may sometimes prove to be substantial where farmers are uninformed, disorganized or unable as individuals to match the knowledge, skill and power of those with whom farmers deal.

Cooperatives might also be used to develop new purchasing and marketing arrangements to give independent farmers some of the advantages of vertical coordination, yet permit the farmer to retain greater managerial latitude than allowed under most contract terms. For example, cooperatives might be used to bring to small scale cattle feeders in the Midwest some of the purchasing and selling advantages enjoyed by large scale cattle feedlots in the West. Cooperatives might be used to provide specialized management services to farmers. Where close vertical coordination would be essential for efficiency, farmers have the option of forming cooperatives to integrate forward into processing and distribution.

In some market situations, cooperatives may find it advantageous to build positions of market strength in order to represent producers more effectively in

competition with other firms or to countervail the market power of other buyers or sellers.

In addition, group efforts of farmers, either through cooperatives, farm organizations, or other agencies, might initiate beneficial changes in contracts between farmers and processors or other integrating firms. Possibilities for different kinds of arrangements, such as franchises, in which the franchise-granting firm might be either a cooperative or noncooperative corporation, could be explored. Coordination efficiencies, which would be mutually beneficial to farmers and purchasers of farm commodities might be obtained through organized group action. Group programs of information and education can lead to improved efficiency and to improved marketing skills for members. New techniques for using the services of futures markets might be developed which would bring their potential benefits more readily to farmers and small firms. Limited equity problems and grievances of members could be dealt with in organized groups. Joint ownership and perhaps joint management of large size production units might prove desirable.

So farmers have some alternatives open to them, even with no change in present policies. More group and cooperative efforts of farmers can aid in preserving for the farmer some of the managerial latitude considered essential in family farm agriculture. But we must recognize the limitations that are inherent in the structure of most of farming if the objective is to give farmers some influence over the stability and level of farm income. Although farms in the future may be counted in thousands rather than millions, they will still be selling raw, undifferentiated products and be too numerous, diverse and scattered, in the absence of Government help, to control supplies in ways to influence significantly the general level of price. Galbraith sums it up this way: "Self organization by farmers . . . to regulate supply and protect their incomes is a pipe dream." (*4*).

This brings us to the remaining two alternatives. One considers legislation which would restrict size directly. The other would increase the organizational options open to farmers.

Legislation to Restrict Farm Size

DIRECT restriction of farm size by limiting the number of acres or volume of sales per farm might be an effective way to control farm size and keep a large number of farms. Laws could also be passed to prohibit absentee or nonfarm corporation ownership of land.

An indirect method of discouraging large scale operations would be to alter income tax schedules so that small size would be encouraged and large size discouraged. Tax allowances and treatment of capital gains might also be changed to make agricultural land less attractive to outside investors. A low limit could be set on the amount of government payments per farm, or government payments could be graduated, becoming less liberal as size of business increased.

However, these and other possible techniques or government programs for restricting farm size would not assure that the management and risk-taking functions would remain intact in the hand of farmers nor that farm incomes would be satisfactory—unless the legislation would attempt to deal with these matters, too. It might be argued, further, that restricting farm size would retard efficiency and technological progress in agriculture.

Enabling Legislation to Expand Organizational Options

BECAUSE of the number, diversity, and geographical separation of farmers, they frequently are unable to coordinate their individual production efforts, or to negotiate effectively with buyers by means of available organizational devices, such as cooperatives and marketing orders as presently authorized. Increased flexibility and opportunity for group action are often needed. In responding to this need, the National Commission on Food Marketing concluded that marketing orders and agreements should be authorized for any locally or regionally produced farm product (*10*). The idea of a new device, termed an "Agricultural Marketing Board," was also proposed.

Essentially an extension of a marketing order, such a board could be voted into effect by producers and could regulate production or marketing, and negotiate prices. Besides an administrator representing the Secretary of Agriculture, each board would also include representatives of handlers and the public.

The Commission further believed specific legislation necessary to protect the right of farmers to

organize, that is, to prevent obstruction, boycott, or intimidation in group activities of farmers to increase their bargaining power.

Secretary Freeman recently discussed the possibility of legislation creating a National Farm Bargaining Board, which would authorize product bargaining units to represent growers if voted in by growers (*3*). He also mentioned the possibility of legislation authorizing broader use of marketing agreements.

Other new devices which would facilitate joint efforts of farmers in production, in marketing, or in the acquisition and transfer of farm property might be considered. Legislation could make it easier for cooperatives to gain a larger role in the total food and fiber sector of the economy, if this were deemed desirable.

Discussions along these lines are attempts to deal with the inherent instability of agricultural supplies, prices, and incomes and with the weak bargaining positions in which producers often find themselves. They are efforts to provide the farmer with institutional devices that would enable him to participate in group decisionmaking and perhaps accept some output restraints in order to gain, in return, greater influence over his future destiny and perhaps be able to recover or retain managerial independence which would otherwise be lost.

SHOULD THE FAMILY FARM BE PRESERVED?

WE must now face up to the question of whether it really makes any difference if the family farm, defined not only in terms of size but also to include a reasonable degree of managerial independence, vanishes into history. To answer the question I will consider the family farm in four ways: in terms of morality, democracy, efficiency, and the economic organization of society.

First, with respect to morality, Thomas Jefferson declared "Those who labor in the earth are the chosen people of God, if ever He had a chosen people, whose breasts He has made His peculiar deposit for substantial and genuine virtue. Corruption of morals in the mass of cultivators is a phenom-

enon of which no age nor nation has furnished an example."[3] And even as late as 1946, in the proceedings of a conference on family farm policy, we find the following:

"The family farm permits and encourages the development of a strong neighborhood and community life. Good schools, churches, co-operatives, and inexpensive forms of recreation thrive in communities of family farms. Under a system of large-scale commercial farms, these valuable social institutions are replaced by poolrooms, honky-tonks, cheap picture shows, and farm labor camps. The family farm does not produce flashy back-slapping personalities, but it does produce men of strong character and moral consciousness. Neighborliness, honesty, industry, and dependability are characteristics of people raised on family farms." (*7*).

Yet there have been other views. Abraham Lincoln once observed that farmers appeared to be no better or worse than other people. If that was so a century ago, it probably is even more true today, since agriculture, in the words of Paarlberg, is losing its uniqueness (*13*).

We probably cannot demonstrate whether people from family farms are more or less corrupted, perverted, or depraved than other people. In statistical language, the variability within groups is probably too wide to detect a difference between groups. We may have our own ideas about the morality of farmers, but the case for preserving the family farm will need further arguments on its behalf.

A related idea in the development of our country was that an agriculture made up of family farms was the backbone of democracy. Jefferson believed and affirmed the idea, which goes back to Aristotle. A penetrating examination of the idea was undertaken in the 1940's by the late president of Yale University, A. Whitney Griswold, in which he studied England, France, and the United States—three countries which have taken the lead in interpreting democracy to the modern world. He wrote as follows:

"Democracy did not spring full-flowered from the soil. It has grown from men's minds and spirits, in the commercial and industrial atmosphere of cities as much as—some would say more than—in the agrarian atmosphere of the country." (*6*).

[3] Quoted by Edward Higbee, *Farms and Farmers in an Urban Age*, The Twentieth Century Fund, New York, 1963.

If we accept Griswold's persuasive conclusions, we again must look further in order to justify saving the family farm.

An argument that some of my colleagues make is that a family farm of adequate size is more efficient than any other organizational pattern of agricultural production. They have strong arguments on their side. One of these is that many units of 1–2 man-years in size have survived and still dominate the countryside. We need to recall, however, that the managerial function is slipping away from several of these units. We must also recognize that with increasing specialization, possible complementary relationships among enterprises decrease and the farmer's work becomes easier to routinize so that it can be supervised from a greater distance.

Yet it is certainly not apparent that family farm agriculture need be less efficient than alternative organizational patterns, or that it needs to be with new institutions or techniques of management and marketing. If this is true, society will not suffer productivity loss by taking steps to keep the family farm.

This brings us to the final and most forceful argument for preserving and strengthening the family farm, that of supporting decentralized decision-making and diffused economic power in the organization of our society. Economics teaches and history verifies that if a firm or small group of firms grow large in relation to the market, they generally increase their influence over the livelihood of others and turn terms of trade in their favor.

Our basic philosophy is in favor of a market economy, but for it to work effectively, buyers and sellers should be sufficiently numerous and vigorous to impose competitive checks on each other. It has been our national policy to take steps from time to time which would nourish competition, sometimes by restraining excessive power, sometimes by encouraging new competitors or enabling weak competitors to become stronger.

Strengthening managerial latitude of independent farmers and firming their market positions as individuals and in groups would be in our national tradition toward balancing economic power in society. It would also give farmers greater influence in shaping the kinds of production and marketing systems which are evolving so rapidly and which are affecting their lives, their role and their managerial freedom so profoundly. The future organizational

structure of agriculture is the central agricultural policy issue today and one of the most critical farmers have faced. Their independence and economic status relative to other groups are at stake.

Farmers enjoy a wellspring of good will in the minds of many nonfarm people, and they would seem to have a natural bond with consumers. The mutual interests of farmers and consumers might well be developed to the benefit of both groups. Society has a vital interest in a steady supply of good wholesome food. Farmers are anxious to provide it and to see the inherent attributes of good food maintained throughout the marketing channel.

In respect to price, I think most citizens would not want to consume slightly lower priced food if this were the result of consistently inadequate returns to farmers—or to any other group. This appeared evident in the housewife demonstrations against food retailers in 1967, when the farmer was not blamed. In fact, some consumers were quoted as saying they would not object to paying a little more for food if they could be sure it would get to the farmer. Consequently, program proposals to benefit producers would not necessarily be resisted by consumers and might be actively suported if potential consumer benefits, such as more steady supplies of reliable quality food, were also a part of the programs.

Our analysis leads to the conclusion that an agriculture made up mainly of family farms, in which considerable managerial independence would be retained by the farm family, probably can be saved. We have also suggested that it may be in the best interest of society to preserve such a structure in order to help decentralize decision making and diffuse economic power more broadly in the economy. If farmers want to preserve the family farm, they have some options, and can probably obtain additional ones if they desire, to help them retain this organizational pattern in the agriculture of tomorrow.

LITERATURE CITED

(*1*) Breimyer, Harold F,
1962. the three economies of agriculture. Jour. Farm Econ.. 44: 689.

(*2*) ———
1965. individual freedom and the economic organization of agriculture. Univ. of Ill. Press, Urbana.

(*3*) Freeman, Orville L.
1967. in union there is strength—labor can do it, why can't you? Address before the Nat. Grange Centennial Convention, Syracuse, N.Y., Nov. 18.

(*4*) Galbraith, John Kenneth.
1966. the farm problem and the policy choices. *Chapter in:* Problems of the American Economy. W. W. Norton & Co., Inc., N.Y.

(*5*) ———
1967. the new industrial state. Houghton Mifflin Co., Boston.

(*6*) Griswold, A. Whitney.
1948. farming and democracy. Yale Univ. Press, New Haven.

(*7*) Hamilton, C. Horace.
1947. social implications of the family farmer. *In:* Family Farm Policy, Joseph Ackerman and Marshall Harris, Eds. Univ. of Chicago Press.

(*8*) Madden, J. Patrick.
1967. economies of size in farming. Agrl. Econ. Rpt. 107, U.S. Dept. of Agr.

(*9*) Mueller, Willard, F.
1967. cooperatives' contribution to effective competition. Keynote Address, Cooperative Month Observance, Wash., D.C., Oct. 9.

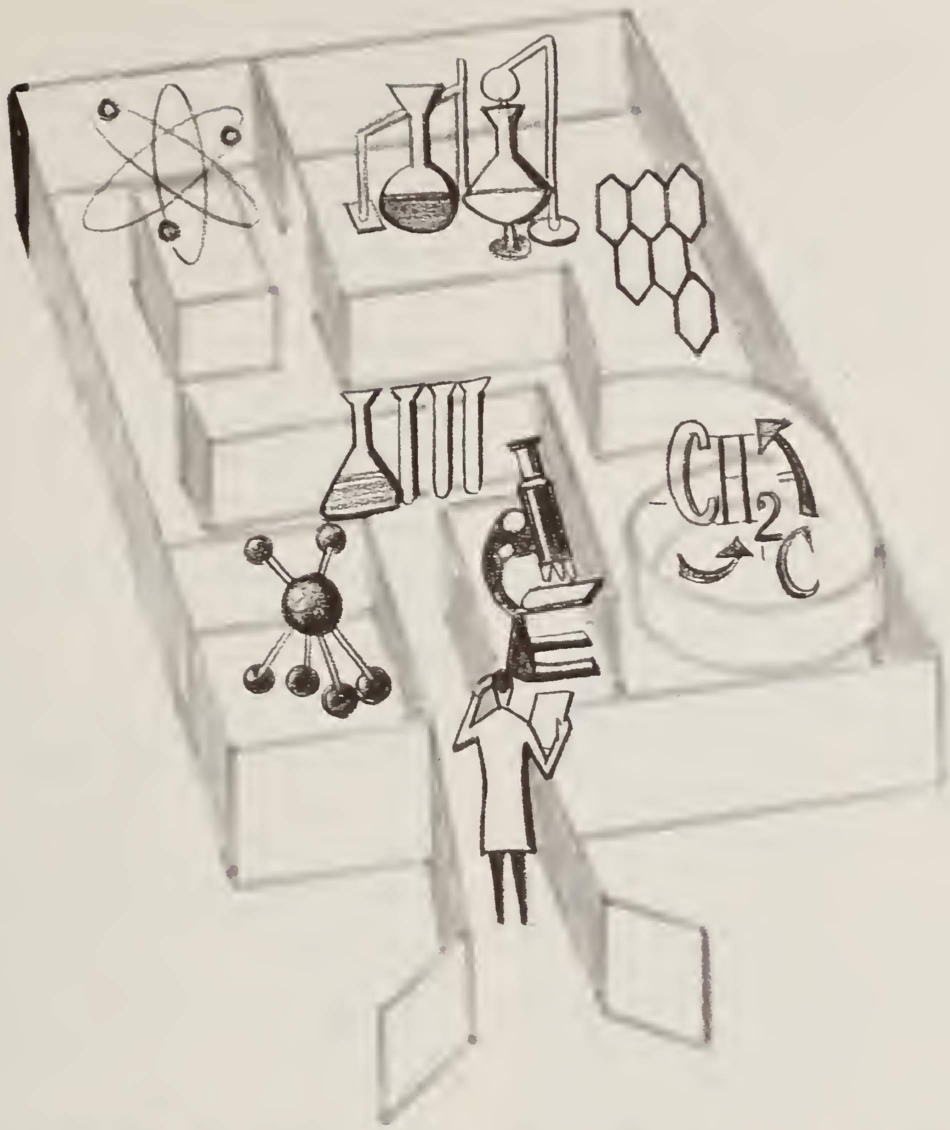
(*10*) National Commission on Food Marketing.
1966. food from farmer to consumer. U.S. Govt. Printing Off.

(*11*) Nikolitch, Radojé.
1965. the adequate family farm—mainstay of the farm economy. Agrl. Econ. Res. 17: 84–89, U.S. Dept. of Agr.

(*12*) Paarlberg, Don.
1964. american farm policy. John Wiley & Sons, Inc., New York.

(*13*) ———.
1967. emerging farm policies. Proceedings of the Seventeenth Nat. Inst. of Anim. Agr. Purdue Univ., April.

(*14*) U.S. Congress.
1967. parity returns positions of farmers. Rpt. to the Cong. of the United States Pursuant to Section 705 of the Food and Agr. Act of 1965 by the Dept. of Agr., 90th Cong., 1st Session, Senate Doc. No. 44, Aug. 10.



THE IMPORTANCE OF BEING SURPRISED IN SCIENTIFIC RESEARCH

ROBERT L. CAUSEY

BASIC research has the principal aim of increasing our knowledge and understanding of the world. A good part of our storehouse of scientific knowledge consists simply of accumulated bits of information acquired through routine fact-gathering research. Much of this information admittedly is useful and interesting and has a wide application to modern technology. But the repeated measuring of a constant, with greater and greater accuracy, is usually not a very effective way to increase knowledge.

As a general rule, the world of science is most interested in surprising new discoveries. For example, it might be much more important for a scientist to discover a new virus than to measure the size of a known virus with a little greater accuracy than is presently available. Of course, surprising discoveries do occasionally result from increasing the accuracy of measurements—such as those that contributed to the discovery of rare gases in the atmosphere by Rayleigh and Ramsay. Rayleigh's

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measurements, however, were not undertaken simply for the sake of greater accuracy. He originally set out to test Prout's hypothesis that the atomic weights are integral multiples of the atomic weight of hydrogen.[1]

Surprising discoveries are those which most scientists do not expect on the basis of present knowledge and understanding. These surprises have a double value. They add to our knowledge; they also reveal gaps in our understanding. Thus, they are a gift and a challenge.

The First Rule of Research

I BELIEVE the world is sufficiently large and complicated that it will continue to surprise us as long as we continue to explore it. Furthermore, this element of surprise plays an extremely important role in the progress of science and in the art of scientific investigation. To make the most of it, a scientist would do well to consider The First Rule of Research: *Always try to maximize your chances of being surprised.*

This rule does not mean that one should do absolutely wild things in the laboratory, for we need some control over our experiments. Like all rules, it must be used prudently. The important question is: How can one try to be surprised? The First Rule has many corollaries which might help a scientist do this.

I call the first corollary *The Principle of Beginner's Luck.* It applies primarily, but not exclusively, when one is making rather unprogrammed observations. This principle says that one has a good chance of discovering something unexpected if he is one of the first to examine a previously unobserved part of the world. Thus, if you are an explorer, you should explore new territory, rather than make detailed maps of old territory. If you do look at old territory, then you should examine it in a new way. If you have an exciting new means of observation, it will enable you to look at a new part of the world. Therefore, one should maintain a constant lookout for new techniques and inventions which could greatly improve his powers of observation and measurement. Consider the dramatic discoveries which were made with the telescope, the microscope, the spectroscope, and X-rays. If a scientist is quick to make use of such new techniques, he will be one of the first to look into a new domain. He can hardly avoid being surprised. This type of exploratory observation furnishes some of the most exciting moments in science.

Another corollary of the First Rule is Max Delbruck's *Principle of Limited Sloppiness,* which, according to George Beadle, "... holds that in carrying out an experiment one must be sloppy enough that unexpected things will be discovered (penicillin, for example), but not so sloppy that the procedures cannot be repeated."[2]

With a little thought, one can concoct other rules to help the experimenter find surprises. But he also needs to know what to do with unexpected discoveries.

Consider that the second prime aim of basic research is to increase understanding. It is possible to have a great deal of knowledge and still have little understanding. We could record fact after fact and still have no idea of whether, or how, they might be connected with one another. To obtain understanding we need to have a theory; that is, a set of hypotheses which explain the wild assortment of observed facts and laws and which connects them together into some kind of coherent pattern.

To see this more clearly, suppose that a comprehensive theory of classical mechanics and gravitation had not been formulated until 100 years after Newton's time. No doubt many more laws of terrestrial and solar system motions (like those of Galileo and Kepler) would have been discovered. But to the very curious these laws would have remained a puzzling collection of apparently unconnected facts. To understand them well requires a comprehensive theory from which they can all be derived with the help of suitable initial and boundary conditions.

The Second Rule of Research

WE have noted that basic research is concerned not only with increase in knowledge, but also with increase in theoretical understanding. This leads to

[1] John N. Howard "John William Strutt, Third Baron Rayleigh," *Applied Optics*, vol. 3, 1964.

[2] George W. Beadle, "An Introduction to Science," In: *Listen to Leaders in Science*, Albert Love and James Saxon Childers (Eds.). Atlanta, Tupper and Love, 1965.

The Second Rule of Research: *Always try to explain what you understand the least.*

This rule does not mean that one should dream up perfectly wild theories. A scientist works on problems which he thinks he has some chance to solve. But within this limitation, he should work on the most perplexing problems. Big problems, such as the cell differentiation problem, will not be solved overnight. But one can at least work on them.

Some would-be theoreticians spend all their time working out the complicated implications of an accepted theory just for the sake of greater detailed knowledge. Such work can lead to many publications, but it is usually rather dull. One might ask: What are the most perplexing problems? How do we know what we don't understand well, until the details of theories are well worked out? The answer is that we can never know for certain how well we understand the world. But at least we can watch for signs of what we don't understand.

Now we can see why surprising discoveries are so important and challenging, for they are often an important sign of poor understanding. Surprising discoveries not only greatly increase our knowledge of the world; they also often require further theoretical development in order to be understood. The very fact that a discovery is surprising means that most scientists did not expect it on the basis of present knowledge and understanding. But the general understanding at a given time is furnished by the widely accepted theories of that time. Thus, a surprising discovery presents the challenge of trying to explain it with the accepted theories. If we succeed, then we will have further developed these theories in an important new way. If we fail, then the surprise challenges us to invent new theories which can account for it. In extreme cases the discovery might be inconsistent with the accepted theories, and then it will challenge us to reject these theories and replace them with revolutionary new theories.

Because of these observations we are led to formulate a corollary of the Second Rule of Research. This corollary is the *Law of Diminishing Surprise,* which states that science progresses in part by the theoretical explanation of surprising discoveries. Thus, the artful theoretician will continually keep his ear to the ground for new discoveries, and when he hears of a good one he will try to account for it.

This procedure might be valuable in another way. Much has been written about the difficulty of inventing theories, and there are many stories about the mental gymnastics of theoretical problem solving. I believe that the solutions of theoretical problems are often suggested by fortuitous clues which are presented to a man who has long worried about a certain problem. Surprising discoveries can sometimes be such clues.

Another important corollary of the Second Rule of Research is the *Rule of Unity.* Theories are used to furnish understanding of observed phenomena, but we can still search for further understanding of our theories. This kind of understanding will result from still more general theories which tend to simplify and unify the theories we have presently available. The *Rule of Unity* says that we should always work toward the unification of science.

One of the most important kinds of unification results when the theories of one branch of science are reduced to; that is, explained by, the theories of a more general science. When such reductions occur, they not only produce greater understanding, but they usually result in enormously more rapid progress in the science which is reduced. Great advances in 20th century chemistry have partly resulted from the quantum mechanical account of chemical bonds, which was an important breakthrough in this reduction of chemistry to atomic physics. The keystone of this reduction was the identification of molecules with structures built from atomic parts so that these structures could be accounted for by quantum atomic theory.

Reductions very often involve important identifications. Franklin identified lightning with electrical discharges. This was not exactly a reduction, but it allowed people to study lightning in a much more productive way, and also it raised many interesting questions about the charging of clouds, the voltage of the bolts, and other phenomena. Right now, we are witnessing very exciting developments in biology which have resulted from the identification of genetic materials with nucleic acids.

Research is given an important sense of direction by the belief that the world is built up from simple things in a hierarchical pattern of structures of ever increasing complexity. A first step toward the unity of science consists of trying to decipher this hierarchy. But it is a little like a jig-saw puzzle. It would not be efficient to begin with one piece and work continuously outwards from that piece. Instead, we need many people working all around

the border trying to construct the overall general pattern. After this is done we can fill in the details. Therefore, it is important to have research done on all levels, while at the same time searching for possible connections between levels.

The Third Rule of Research

THE Third Rule of Research, *The Law of The Jungle,* states that only the fittest theories should survive. Hence, any theory must be severely tested. If a theory only accounts for the facts which it was invented to explain, then it is likely to be branded ad hoc and not given much attention. A really good theory is one which not only explains what motivated it, but also allows one to predict from it other phenomena—some of which hopefully have not been observed. If a bold new theory produces surprising predictions, then one of the severest tests we can give it is a test of these surprising predictions. If the test results in the effect predicted, we not only confirm the theory to some extent, but we also make a new discovery.

One characteristic of the sophisticated scientist is the courage to test theories, even his own, very harshly. For instance, Feynman says, "One of the ways of stopping science would be only to do experiments in the region where you know the law. But experimenters search most diligently, and with the greatest effort, in exactly those places where it seems most likely that we can prove our theories wrong. In other words we are trying to prove ourselves wrong as quickly as possible, because only in that way can we find progress." [3]

I stated earlier that the experimenter should try to maximize his chances of being surprised. If he is looking in a new area, or if he has an exciting new technique of observation, he has a good chance of being surprised by rather unprogrammed observation. But we don't always have exciting new techniques of observation. Most experiments are designed to test theories. Of course, many of those theories are just very tentative hypotheses.

Albert Szent-Gyorgyi is aware of this in his own work. He says: "While I work I usually do not know where I am going. I just follow hunches. I dream up all sorts of theories at night and then disprove them in the laboratory the next day. Checking a hunch

[3] Richard Feynman, *The Character of Physical Law.* Cambridge, M.I.T. Press, 1965.

sometimes I see some discrepancy, something unexpected—then I follow it up. Success depends on whether the hunch was good or bad."[4] Szent-Gyorgyi admits that he was quite lucky in his discoveries.

Sometimes testing a new theory will lead to a lucky accidental discovery of something unrelated to the theory. The discovery of the atmospheric rare gases is a good example of this. (In that case the theory, Prout's hypothesis, was not chronologically new, but it was new in the sense that it was still rather controversial.)

The more usual situation, however, involves a new theory which predicts something surprising; that is, something not expected on the basis of previous knowledge and understanding. In general, one should test the most surprising predictions he can make from a theory. In this way, he not only tests the theory severely, but also has a chance to observe something very new. Thus, theories play an important role in both explanation and discovery.

Without theories we could not design most of the experiments we do. Many of the experiments of Meselson, Kornberg, and Benzer would not have even been imagined before someone had discovered the structure of DNA and hypothesized how it replicates. A classic example of a bold theoretical prediction was Mendeleev's prediction of the existence and properties of unknown elements. Another striking example was Einstein's prediction of the gravitational bending of light rays near the sun. I cannot imagine anyone looking for, and discovering, this bending prior to its prediction by a theory.

* * *

In very general terms, one might say that the art of scientific investigation consists of the following: Look for surprises. If you find some, invent theories which explain them and thus diminish the surprise. Then, use your theories to predict new surprises, and test these theories by trying to produce these new surprises. This is the way science progresses.

The several heuristic rules proposed in this paper might enhance the rate of progress. Undoubtedly many other useful maxims could be devised. But rules alone will not guarantee success. There must also be the motivation of curiosity and the inventiveness of imagination.

[4] Quote from an interview with Albert Szent-Gyorgyi. In: *The Way of the Scientist.* New York, Simon and Schuster, 1966.

Booby-Trapping to Control Insects

PRELIMINARY research in Australia indicates that some insect pests can be booby-trapped and used to kill or incapacitate their mates.

M. J. Whitten and K. R. Norris of the Commonwealth Scientific and Industrial Research Organization obtained a strain of Australian sheep blowflies (*Lucilia cuprina*) that had developed resistance to dieldrin, dabbed them with the chemical and then released them among a colony of flies still susceptible. The kill ratio was impressively high. Each booby-trapped female accounted for up to 100 males which absorbed a lethal dose of dieldrin during attempted mating. For some reason, males were not nearly as dangerous when booby-trapped as the females.

The method need not be restricted to instances where resistance had developed as a result of continuous field use of a certain insecticide. Resistant strains could be deliberately produced in the laboratory by repeated exposure to a poison, selected perhaps because it would be too dangerous for general spraying. Since booby-trapping confines toxic contamination to the target pest, a wider range of poisonous chemicals can be used without increasing the risk to man, his animals, or the environment generally.

The Australian sheep blowfly has already developed field resistance to dieldrin, but tolerance to the organo-phosphorous group of insecticides has appeared only in some localities. Clearly, a ready-made opportunity to implement the booby-trap system currently exists and every effort will be made to exploit it.

From: *Australian Science Newsletter*

FORUM

NUTRITION: AN ELEMENT IN GNP

BY the end of the second quarter of 1968, the U.S. Gross National Product[1] (GNP) had reached the thought-staggering sum of $852.9 billion. This monetary value of our national income and productivity is the direct result of ideas carried to fruition and executed by people to yield products ultimately used by and for people. And yet people, as the resource from which this productivity stems and as the beneficiaries of it, are unidentified as a discrete component in GNP.

[1] The Gross National Product is an accounting system by which we measure national income and productivity. It assesses the level of prosperity as indicated in a pooled evaluation of (1) personal consumption expenditures, (2) gross private domestic investment, (3) net exports of goods and services, and (4) government purchases of goods and services. Within these broad categories, value is assigned to the total U.S. output of durable and nondurable goods,, services, and structures in governmental and private sectors in a given year—all of which are reflected in Gross National Product quotations and labelled, for convenience, GNP.

This article was adapted from a paper presented by the author to the West Virginia State Nutrition Council, Cacapon State Lodge, Oct. 4, 1968.

Why should we attempt to identify people as a component in GNP? To answer this question, we must consider that the requisites for optimum human productivity include (1) a desirable mesh between mental and physical capability, (2) adaptability to environments of social challenge, and (3) functional use of these attributes. Within this context, we must embrace the total structure of the practical living processes, because ideas evolve in circumstances of both work and play. A mutual exchange in satisfaction between the two can be identified. Nutrition is fundamental to each of these three requisites; therefore nutrition, as an element in GNP, seems wholly justified.

The American Profile

ONE of the first steps in approaching nutrition-related problems is to characterize the pertinent nutrition-related profile. In this instance, it may be described as 201 million (the U.S. population in June, 1968) men, women, and children of all ages and levels of attainment—some 84 million of whom are in the labor force and about 3.6 million unemployed.

These are people who endure a wide variation in resources to meet their needs for food, clothing, and housing but who are meeting these minimum needs and supplementing them with other acquisitions at a level of nearly $528 million in personal consumption expenditures in the second quarter of 1968.

These are people who can listen, speak, see, walk, run, think . . . and, in the process, produce ideas and translate them into action. But these activities are modified by all the factors that regulate the physiological and social machine that we describe as human. Such factors as age, activity, health status, economics, preference, and social circumstances are fundamental to the modifications. Nutrition is a composite base in each. Nutrition is the balance between intake of nutrients and output potential of living systems. This potential output is the sum total of actual productivity and untapped resources for productivity.

It does not take a research base to recognize gross differences in ages, facility to act, and aggravated poor health. Old and young, active and inactive, sick and well are distinctions used in the common vernacular. Our research base does tell us there are

reasons for these differences and gives us some specific measures for diminishing the undesirable ones. The research base also tells us there are detectable differences in internal functions even before these external characteristics are obvious to the casual observer. The research base allows some suggestions for circumventing and alleviating undesirable internal function, which should be reflected externally.

Nutrition Guidelines

THE Food and Nutrition Board of the National Academy of Sciences offers guidelines on specific nutrients for discrete categories of age, sex, and pregnancy to maintain optimum health. These guidelines are presented as recommended daily allowances and predicated on a firm research base. But they do contain limitations, which reflect gaps in our knowledge. As research progress permits, the guidelines are revised. It should be remembered, however, that the values for daily allowances are only guidelines, and this was their intended use. These allowances do not necessarily describe requirements for each individual in a practical circumstance. But this limitation should not prevent their utility for some immediate benefits to consumers.

We are willing to accept the GNP value as an indicator that we are a prosperous nation, and yet we know there are patches of gross poverty in our nation.

We are willing to accept a value of $2,918 as our per-capita disposable income, and yet we know some of our population has less than this amount for an entire family.

We are willing to accept an average life expectancy of 70.1 years, and yet we are aware of daily deaths covering the whole age spectrum from the moment of birth and beyond.

Should we not be willing to accept that we do have quantified reasonable targets for calories and some nutrients? [2] Can we afford to disregard the guidelines in our present nutrient composition data for food resources just because they are yet to be extended?

There is comfort in the caution that requires validated evidence—prior to recommendations—for nutrient allowances as a reasonable target for nutrient intake. There is encouragement in the existence of systems at the Federal, State, and local levels for extending the base of information and translating this to benefits at the consumer level. The national status of human resource development and the GNP will ultimately benefit.

Nutrition has been identified as a national problem with high priority for resolution. We must credit at least part of this intensification of interest to the concern for food to meet the needs of an ever expanding world population and the U.S. potential for assistance, and part to cries from the people for emphasized attention to hunger in our nation. Nutritional improvement is a current emphatic national goal; its program of implementation must logically accept both these justifying concerns as priorities.

An economic criterion of low-income families as, theoretically, the most fertile resource for nutritional improvement is well founded, since access to nutrients is the most basic requirement (aside from the human) in nutrition. Family economics is often the limiting factor in having this access.

The Role of Agriculture

EFFORTS of the U.S. Department of Agriculture directed toward nutritional improvement are carried on cooperatively with the State agricultural experiment stations. The USDA program is long-standing and consistent with the responsibility under the government code to acquire and diffuse useful information on agricultural subjects in the most general and comprehensive sense. In its role, agriculture has an input in each GNP category, although it is classically listed only under farm business.

The machinery is well developed to expedite the functions of agriculture. Within its organizational framework, one discerns food and people as the key words in the missions of agriculture. Food and people, of necessity, involve human nutrition.

Continuing research and evaluation augment efforts to strengthen the research base for nutritional guidelines, beneficial food resources, and channels of access. Answers to questions of why a nutrient is needed and by whom, what changes are desirable in food resources, what are the most efficient chan-

[2] The 1968 revision of Recommended Dietary Allowances will show extensions in distinction of age groups and values for certain vitamins and minerals not previously included.

nels of access to food and use by the consumer—these are among the basic considerations in research plans.

In 1965 there were more than 170 publications reported from food and nutrition research programs supported by USDA to help provide these answers. State agricultural experiment stations contributed 120 of these. USDA, HEW, and OEO are participating in an intensive coordinated effort for nutritional improvement. Food distribution programs for school children and families are well established and newer approaches are being developed. USDA maintains liaison with the Food and Nutrition Board of the National Academy of Sciences, and is the lead agency for the Interagency Committee on Nutrition Education. USDA has representation on the Interagency Committee on Children and Youth and is participating in the Model Cities Program. Nutrition is a component in each of these ventures.

USDA provides support and technical advisory resource to research programs on food and nutrition in the State agricultural experiment stations through the Cooperative State Research Service. Forty-seven States are now conducting more than 200 research projects on human nutrition. In addition, there are six active regional projects. A typical example of the scope in these regional efforts is evident in a recent planning session where scientists from 18 States and USDA met to develop plans for intensifying research on relationships between food, fat, and atherosclerosis.

Approaches for Improving Nutrition

LET us assume, for purposes of further consideration, that our food supply, the guidelines to use it, and the machinery for meshing the two are adequate. The remaining most critical issue, then, is actual consumer use. This is our primary mutual concern. Let us further assume there is available in local food markets an adequate representation of how industry has applied our present nutrition knowledge; and that the benefits of school lunch and family food distribution programs have been secured to their practical maximum. Let us acknowledge that there is a functioning State Extension Service appropriately liaisoned with the Federal Extension Service. On these premises and facts, we can pose other considerations that relate to the consumer level.

Consider, for example, a few simple science principles that suggest approaches for improving nutrition.

All elements do not have the same appearance and neither do compounds from their combinations. Carbon does not resemble oxygen. Carbon dioxide does not resemble water. People do not look alike even if the parentage is identical.

Chemical substances do not respond alike under similar conditions of challenge. Alcohol and water mix easily; oil and water do not. Strong acids and water not only mix, but often do so with violent demonstration. People do not respond alike. Examples of turning the other cheek are legend as are examples of an eye for an eye even in the same family. Some people are known to be allergic to agents—and sometimes the agent is in the diet.

To synthesize a desired product, all required reactants must be available at the time of reaction. Food plants synthesize grain, fruits, and vegetables. Production animals synthesize meat. People synthesize skin, hair, bones, and numerous body tissues, although the ultimate function of the human being is far nobler than mere synthesis of tissue.

These are predictable conclusions confirmed through components in the scientific approach—keen observation, documentation, and evaluation for frequency of occurrence.

These and similar comparisons suggest a need to convince people through educational programs that:

- Nutrition is as personalized as a fingerprint and vital to the living process.
- The food-based resource for recommended daily allowances provides substances which were themselves parts of a living system and often duplicate multiple units in the chemical pattern needed for human body function.
- Nutrients are chemicals, and excessive intake of some chemicals produces toxic effects.
- Undesirable nutrition is based on what a person eats in comparison to his personal needs. Moderate-to-high income plus an inadequate relation between intake and requirements can be equated to poor nutrition. Low income plus an adequate relation between intake and requirements can be equated to good nutrition.

Can we enlist the aid of people to share their patterns of diet selection in ways meaningful for reliable documentation and ultimate evaluation? Can we get them to cooperate in companion biochemical assessments of their nutrition? Correlation of these kinds of information may reveal nutritional groups and methods for detecting them.

Can we influence a closer coordination of the medical, social science, and nutrition professions in food action programs and research?

Can we enlist the aid of these and other professions to develop science-based program materials for a consumer audience?

Can we project an image for nutrition favorable to attract more young people to consider it as a profession?

The accomplishment of these goals, coupled with progressive research and cooperation of industry and agriculture, would seem to assure a long-term nutritional improvement among the American people.

The GNP that would accompany such a concerted, national improvement in mental and physical facility may well be phenomenal.

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